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Two Sections—Section One

MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

Spring Meeting Papers

A supplement to this issue of MECHANICAL ENGINEERING contains a number of papers that will be read at the Milwaukee Spring Meeting of the A.S.M.E., May 18-21, 1925. It also contains synopses of other papers that will be available in pamphlet form.

This scheme of advance publication of meeting papers has been devised for the purpose of stimulating thorough discussion, which develops the strength or weakness of the papers and adds to the interest the meeting has for those attending.

MAY 1925

THE MONTHLY JOURNAL PUBLISHED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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F. W. Ming

C. J. Fechheimer

W. H. Carrier

D. C. Lindsay

R. E. Flanders

Contributors to this Issue

Julius Kruttschnitt, chairman of the executive committee of the Southern Pacific Company, is the author of the leading paper in this issue on The Engineer as a Railroad Executive. Mr. Kruttschnitt is an alumnus of Washington and Lee University, being graduated in 1873 with the degree of civil engineer.

In 1878 when he entered the service of the Morgan's Louisiana and Texas Railroad & Steamship Company (now a part of the Southern Pacific Lines) as resident engineer in charge of construction work. Completing that work in 1880, he was retained as roadmaster, receiving successive promotions as assistant chief engineer and general roadmaster, chief engineer and superintendent, assistant general manager of the Southern Pacific Lines east of El Paso, and in 1889 was made general manager of that system. In 1895 his jurisdiction as general manager was extended over the entire Southern Pacific System with headquarters at San Francisco. This position, with additional responsibilities as vice-president and later as assistant to the president, was retained until 1904 when he was moved to Chicago and was placed in charge of the operation and maintenance of the combined Union Pacific and Southern Pacific properties with title of director of maintenance and operation. On the separation of those systems in 1913, Mr. Kruttschnitt was elected to his present position of chairman of the executive committee of the Southern Pacific Company with headquarters at New York.

* * * * *

Carl J. Fechheimer, author of the paper on the Performance of Centrifugal Fans for Electrical Machinery, was born in Cincinnati, Ohio, in 1882. In 1904 he received the degree of B.S. in M.E. from Purdue University and the following spring he received his M.E. from Cornell. From 1905 to 1910 Mr. Fechheimer was employed in the engineering department of the Allis-Chalmers Company designing a.c. generators and motors. For the next four years he was in charge of a.c.-generator and motor design for the Crocker-Wheeler Company. Since 1914 he has been with the Westinghouse Electric and Manufacturing Company where he is now research engineer in the power-engineering department.

W. H. Carrier and **Daniel C. Lindsay** are co-authors of the article on Temperatures of Evaporation of Water into Air. Mr. Carrier, president of Carrier Engineering Corporation, was graduated from Cornell University in 1901. From that time until 1915 he was associated with the Buffalo Forge Co., Buffalo Steam Pump Co., and the Carrier Air Conditioning Co. of Buffalo, N. Y., first as research engineer and later as chief engineer in charge of the design and testing of fans, pumps, heaters and air-conditioning equipment. In 1915, with Mr. J. I. Lyle, he organized the Carrier Engineering Corporation as an engineering and contracting company specializing in air conditioning, cooling, and drying in industrial work.

Mr. Lindsay, attended Cornell University from 1915 to 1917 and again from 1919 to 1923 under the Telluride Association Fellowship, where he took a B.A. degree in 1921 and spent two residence years in the graduate school. In 1917 and 1918 he was in the employ of the Carrier Engineering Corporation and was engineer in charge of the air-conditioning equipment at the United States ammonium nitrate plant at Perry Point, Md. From January, 1923, to March, 1924, he was attached to the United States Bureau of Standards as associate physicist, dealing with problems in the drying of ceramic wares. Mr. Lindsay rejoined the Carrier Engineering Corporation as physicist in April, 1924.

* * * * *

Ralph E. Flanders, the discussion of whose paper on Design, Manufacture and Production Control of a Standard Machine, published in the December, 1924, MECHANICAL ENGINEERING, appears in this issue, was born in Vermont in 1880. After his graduation from high school in Central Falls, Rhode Island, he served an apprenticeship as a machinist and draftsman from 1897 to 1901. He then became designer for the International Paper Box Machinery Company at Nashua, New Hampshire. From 1905 to 1910, Mr. Flanders was associate editor of *Machinery* and went from there to be engineer for the Fellows Gear Shaper Company. Since 1912 he has been director and manager of the Jones and Lamson Machine Tool Company and he is recognized as an authority of machine-tool design. Mr. Flanders is a past-president of the National Machine Tool Builders' Association.

* * * * *

Frederick W. Ming, author of the paper on the Standardization of Machine Drafting, is instructing at the Polytechnic Institute of Brooklyn in mechanical engineering. After studying at Cornell University for four years, he was engaged by the Ithaca Gun Co. as a production engineer. He later was called to the Davenport Manufacturing Co. as chief engineer in the manufacturing of U. S. Gun Mounts. In 1920 he was appointed mechanical engineer for the Interstate Commerce Commission at Washington, D. C.

* * * * *

Leon Cammen, M.A. author of the paper on Principles of Metallurgy of Ferrous Metals for Mechanical Engineers, is associate editor of MECHANICAL ENGINEERING, and in the past ten years has done a considerable amount of work on the metallurgical problems connected with the centrifugal casting of metals and the production of metal alloys.

A.S.M.E. SPRING MEETING

Hotel Pfister, Milwaukee, May 18-21, 1925

A supplement to this issue of MECHANICAL ENGINEERING is devoted exclusively to the A.S.M.E. Spring Meeting. It contains a number of complete papers that are to be presented at Milwaukee and synopses of papers that are issued on request in pamphlet form. Members who attend the meeting are urged to bring the supplement with them.

Current issues of the A.S.M.E. NEWS contain information about the interesting program of entertainments and excursions planned by the Milwaukee Committee.

MECHANICAL ENGINEERING

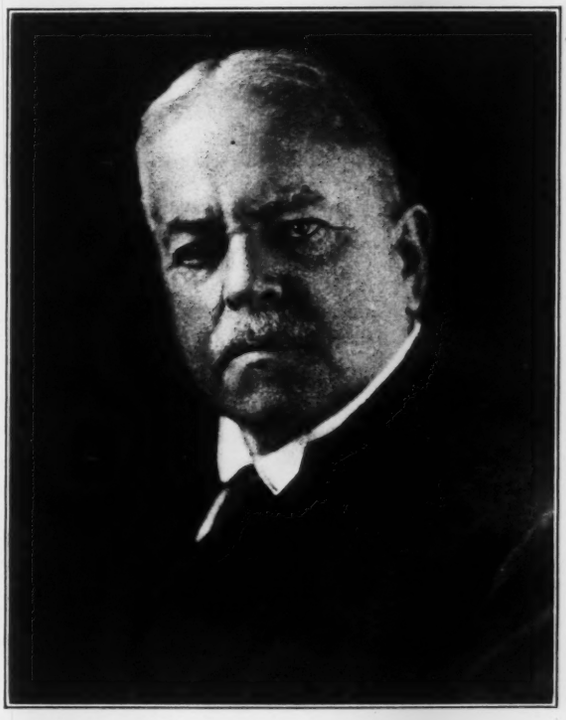
Volume 47 May, 1925 No. 5

The Engineer as a Railroad Executive

The Problems Confronting the Responsible Managing Officer and the Extent to Which He Has Thus Far Solved Them—How the Engineer Has Risen to New Responsibilities and What Recognition Has Been Accorded to His Fitness to Adminster Railroad Properties

By JULIUS KRUTTSCHNITT,[1] NEW YORK, N. Y.

TO JUDGE CORRECTLY of the qualifications of a man for the position of railroad executive we must make a comprehensive survey of the duties devolving on him under present-day conditions, and of the difficulties which he has to overcome. Not only must we consider the problems that require solution but we must take into account the limitations imposed by law on the revenues of railroads and the extent of control of their expenses that the executive is permitted to exercise. It seems appropriate, therefore, to introduce a quite full outline of the problems that confront the responsible managing officer, the extent to which so far he has solved them, and to what extent they remain unsolved, after which an endeavor will be made to show how the engineer has risen to new responsibilities, and what recognition stockholders and directors of railroads have accorded to his fitness to administer their properties.



JULIUS KRUTTSCHNITT

Fundamentally a railroad is a huge manufacturing plant designed to convert the energy locked up in fuel into work for transporting persons and property on specially designed roadways. The energy conversion is by means of individually operated locomotive units, and the success of the entire plant, measured by the spread between production costs of output—measured in passenger-miles and ton-miles—and selling prices depends on the efficient working of each individual unit.

To attain the maximum or even moderate success in creating a margin between the cost and sales prices of output, the necessary executive and administrative work can best be done by men specially trained in those branches of knowledge that contribute most to the efficient operation of railroads, on the degree of which depends success or failure; and the most important duty of the chief executive is so to select his official staff as to attain the best results. To pass intelligently on the qualifications of his staff and their recommendations that may reach him—in other words, to avoid being a mere rubber stamp to approve whatever is laid before him—requires a fair knowledge of the functions of each department head by the chief executive.

At the outset let me explain the causes that have brought about the epochal changes in the conditions of the railroads in the first quarter of the twentieth century, conditions that have obstructed successful operation to an extent never theretofore encountered, and then show how American talent has adapted the railroads to these new conditions and so far has averted bankruptcy and ruin.

The rise of prices of all commodities throughout our country that was started by the outbreak of the World War in the summer of 1914, culminated in the United States in May, 1920, when the index number of wholesale prices showed an increase of 236 per cent above the corresponding number in 1900. Starting from the base index number—taken as 100 in 1900—there was a slight fall in 1901, but in 1902 prices were 4 per cent above those of 1900 and, with some reversals, the rise was continuous to the outbreak of the World War when they were 20 per cent higher than in 1900. At the date of our entry into the war the index number of wholesale prices was 120 per cent above that for 1900. The fall from the peak of 236 per cent over 1900 prices in 1920 was rapid—to 83 per cent above those of 1900 in the middle of 1921—since when there have been fluctuations leading to the figure of 94 per cent above 1900 prices in December, 1924.

During the seventeen years from 1900 to 1917 the average railway freight rate in the United States remained nearly stationary. True, there were fluctuations that affected the average, but never sufficiently to raise it over 5 to 7 per cent above the 1900 rate, so that when the United States entered the World War the average freight rate was almost exactly the same as it was seventeen years theretofore; but in these seventeen years average prices had risen 120 per cent and wages of railway employees, 77 per cent. At the beginning of the century, 25 years ago, the average operating ratio for all the roads of the United States was 65 per cent. Under Government operation it rose in 1920 to 94.3 per cent and for the twelve months of 1924, after four years of private operation, it fell to 76.14 per cent. These data are quoted to show how the spread between revenues and expenses has shrunk, and how narrow a margin exists at the present time out of which to pay interest on obligations and dividends on stocks.

It will be observed that the percentage return on investment that was 4.52 in 1900 substantially vanished in 1920 on the return of the railroads to their owners by the Government, and never since that time has equaled the 1900 return. For 1924 it was only 96 per cent thereof, or 4.35 per cent, and it has fallen still farther below the statutory return for two years of 6 per cent, prescribed by Congress as reasonable and allowable, from March, 1920, to March, 1922, and 5¾ per cent from March, 1922, to date.

These figures show the wide difference in the kind of managing talent required on railroads now and 25 years ago. At the end of

[1] Chairman, Executive Committee, Southern Pacific Lines.

Address at a joint meeting, New York, March 18, 1925, of the New York Sections of the American Society of Civil Engineers, American Institute of Electrical Engineers, and American Institute of Mining and Metallurgical Engineers, the Metropolitan Section of The American Society of Mechanical Engineers, and the New York Electrical Society.

the nineteenth century 35 cents net out of every dollar could be turned into the treasury, while at the present time only 24 cents, or 32 per cent less, can be turned in, and it requires the closest kind of management and the services of very much more highly trained executives to meet all money requirements other than mere operating expenses out of 24 cents out of every dollar. To get the most work out of fuel, the largest material item of operating expenses, stresses the efforts of substantially every department on a railroad, and to obtain the best results requires the highest talent in a great many different branches of engineering. The course of civil engineering in our leading universities embraces courses in the allied sciences of mechanical and electrical engineering, and the important principles of physics, chemistry, geology and economics, so that the executive who has enjoyed the training afforded in a civil-engineering course is peculiarly well fitted for coördinating and guiding the numerous operating activities on railroads, and for securing the maximum output of salable products at minimum costs. An analysis of the operations that produce transportation units will show that the engineer who has been trained to secure desired ends in the most practical, efficient, and least expensive way can best contribute to the success of a railroad enterprise, and will indicate the directions in which he should prepare himself in college for executive duties, and will correspondingly indicate to the owners of railroads, other things being equal, the qualifications to seek in managers.

Viewing the railroad, then, as a manufacturing plant designed for the sole purpose of creating the maximum of transportation units out of the minimum of fuel units, the greatest efficiency will be attained by that railroad whose executives coördinate best all departments and concentrate their activities on increasing output, from the sale of which the railroad must secure its revenues.

Enumerating some of the activities of a railroad will show how numerous are the demands made on a chief executive, and at the same time will show, to a certain extent, how the problems that confront him have been partially solved or are still demanding study for their solution.

I—Executive Department

The wise executive will spare no expense in establishing an accounting department to keep track of earnings and expenses, to record the history of operations, to act as general inspectors to expose poor results as prerequisites to their correction; to work up promptly cost data of every important item of operating expense and as promptly to put them in the hands of all concerned. While the experience of the men who make the decisions will usually keep them from going far wrong, yet in matters involving millions in both capital and operating expenses a railroad officer should not be satisfied unless he has definite figures on which to base decisions. The record traffic handled with record efficiency in 1917 was the response of the railroads to the monthly data sheets first issued by the Railroads' War Board; these are now issued in even more detail by the Interstate Commerce Commission and the Bureau of Railway Economics. Fuel accounts kept with individual engineers and firemen and locomotives furnish railroads with data from which to decide definitely what type of locomotive is the most economical for their use, and whether the expense of applying and maintaining some of the many fuel-saving devices is warranted.

The location of a railroad is giving it its constitution. It may be sick almost unto death with accidents of construction and management, but with a good constitution it will ultimately recover. The board of directors, advised by the chief executive, must pronounce on the location of the railroad between its termini; it allots the amount of money to be spent on construction and fixes the grade and curve systems, because the ideally perfect railroad, between given points, should be absolutely straight and of uniform grade, that is, devoid of undulations in alignment or profile. The expense of operation will increase in proportion to the grade and curve resistance involved in departures from the ideal line, and the extent of departure must be authorized by the board, on which devolves the duty of providing the money for construction. Whenever a ton weight is lifted one foot, an amount of work equivalent to moving it 333 ft. over a straight, level track is spent; and every time a ton weight of train is forced through 100 ft. of 1-deg. curve, the work done in deflecting it from a straight to a curved path is equivalent to moving the same ton over $16^2/_3$ ft. of straight, level track. The equated length of the old line of the Central Pacific between Ogden and Lucin, Utah, compared with the new Lucin cut-off line is as 280 to 129 miles: one pound of fuel on the new line moves as much tonnage as 2.2 lb. on the old.

The Executive Department must determine the justifiable outlay to reduce grades and curvature on existing lines, as obviously the expenditure necessary to obtain a straight line between two points without any undulations in grade might be commercially prohibitive. It is therefore of the greatest importance for the commercial success of a railroad to balance the money cost of approaching as nearly as possible ideal conditions with the expected benefits.

Motive power can often be economized by expensive physical improvements, such as installing automatic block signals, redesigning terminals, modernizing roundhouses so as to utilize the residual heat from incoming locomotives to raise steam on outgoing ones, and by increasing the number and lengths of sidings to save delays on the line. On the executive rests the responsibility of balancing the interest, maintenance, and depreciation costs on large capital expenditures against possible savings, and of providing the necessary capital if the investment is justified.

II—Traffic Department

The Traffic Department is the sales department of the railroad, and its contract specifications as to loads in cars and character of service exert a profound influence on net earnings. It requires 41 per cent less power to haul 50 tons of lading in one car than in two of the same class and weight, and 53 per cent more power to haul a given load at 40 than at 20 miles per hour.

III—Maintenance-of-Way Department

The resistance to traction of locomotives and cars varies between wide limits with the condition of the track. The train-resistance figure commonly used of 6 lb. per ton of 2000 lb. at low speed assumes track in good condition. It may very easily be two or three times that amount on track laid with light rail, poorly maintained, in bad surface and with low joints, etc. The heavier the rail and the better the ballast, the easier it is to maintain good alignment and surface, the less will be deflection under loads, and the less will be the work required to force the wheels out of the depression caused by weak and yielding joints.

IV—Maintenance-of-Equipment Department

In 1921 about one-fifth of all locomotive coal, or 25,000,000 tons, was consumed when the locomotives were not doing useful work: in firing up, in waiting for trains, in standing on sidings and passing tracks, in delays at terminals, drawing fire, and waiting at ashpits. This consumption is not productive nor is it all waste. By redesigning terminals and increasing lengths and numbers of sidings the waste can be minimized. Ingenious graphs on which obstructions to traffic are likened to obstructions to flow of water in incrusted pipes, have proven of great assistance in indicating how to increase capacity of line and defer double tracking.

In designing locomotives the features exercising the greatest influence on fuel efficiency are the careful and expert proportioning of engines, boilers, fireboxes, grates, flues, and draft appliances so as to produce by their combination the most perfect device to extract their full heat contents from fuels. But little over 8 per cent of the energy in fuels is now extracted and converted into work.

While it is customary to speak of the waste of fuel in the average locomotive, we must not forget the extremely unfavorable conditions under which it is required to work. Space limitations have thus far prevented the successful use of condensing engines, and thus the locomotive has been deprived of the advantage of 12 to 13 lb. additional effective cylinder pressure. It is driven through all kinds of weather at high speed, so that radiation losses are excessive. To meet the demands made on its boiler for steam, explosive draft must be used, which expels much unburned fuel from the firebox; the resultant effect of all of which is evidenced in low thermal efficiency.

With the increase in the power of locomotives and the use of higher steam pressures, mathematical talent has been called upon to replace rule of thumb in computing stresses and proportioning parts. Questions as to the adoption of alleged improvements are

difficult to decide, as they involve first cost, interest, maintenance and depreciation, their possible effect on engine failures, and the idle time of locomotives while undergoing repairs. Sometimes economy of operation is sacrificed to facilitate adjustment and repairs, as when outside valve gears replaced the original Stephenson link motion.

The practice of buying locomotives regardless of their adaptability to special service, as was done during Federal control, simply because they could be built in quantity at some reduction in cost, is recognized by competent judges as the poorest kind of economy.

The brake thermal efficiency—or percentage of energy in fuel transformed into work—of reciprocating, condensing, stationary steam engines is (boilers excluded) 19.0 per cent, of steam turbines, 19.2 per cent, and of large power plants (average of eight, boilers included), 13.3 per cent; while the thermal efficiency of non-condensing steam locomotives at maximum capacity, equipped with proven fuel-economizing devices, is but from 7.3 to 8.1 per cent.

Some of the problems that have been closely studied and have been solved to a greater or less extent may now be considered.

Brick Arches. Brick arches built into the firebox mix the entering air thoroughly with the combustible gases rising from the fire and save on some types of locomotives about 12 per cent.

Superheating. The advantages resulting from the use of superheated steam are due mainly to

a Prevention of cylinder condensation
b Larger volume of steam per pound.

Since the cylinder takes the same volume of steam per stroke for the same cut-off, it is obvious that substantially fewer pounds of steam will be used for the same work done. Superheating may save 20 per cent of the fuel.

Feedwater Heaters. Feedwater heaters utilize waste heat to raise the temperature of the feedwater, thereby relieving the fuel in the firebox from heating the cold feedwater from an average of 60 deg. fahr. up to 220 deg. and saving about 10 to 14 per cent of the fuel.

The combined average effect of these three devices in saving fuel on passenger and freight locomotives of various types at various speeds in actual service is given below, but it must not be forgotten that these figures vary widely for different locomotives, speeds, and classes of service.

Arch	9 per cent
Superheater	20 per cent
Feedwater heater	10 per cent
Combined average effect of the three devices	34.5 per cent

The savings claimed for the various fuel-saving devices are gross figures. The cost of applying them is quite large, and in some cases not justified by the age or obsolescence of the locomotive; in others it is beyond the financial ability of railroads to apply them; hence we must be careful to balance cost of interest, maintenance, and depreciation against the value of the fuel saved. The net saving so determined—not the gross—will show whether the money to provide the appliances can be providently expended or not. Experience shows that thus tested the gross saving of superheaters is reduced from 20 per cent to about 17.4 per cent, and of feedwater heaters from 10 per cent to about 6 per cent.

Boosters. Under normal conditions a locomotive can haul as much, or even more, load than it can start. The booster consists of a pair of independent engines coupled to the trailer wheels of locomotives, thus utilizing weight not otherwise used for traction in starting and quickly accelerating trains and in reducing violent shocks in starting which are so hard on draft gear and the temper of passengers. As it cuts out automatically at a speed of 10 miles per hour, it uses steam at low speeds when the boiler can oversupply the main cylinders. It is therefore an indirect but valuable fuel saver through increased locomotive capacity. The booster can add about 10 per cent to the starting drawbar pull of heavy freight and as much as 25 to 35 per cent to the starting drawbar pull of lighter passenger locomotives.

Feedwater Purifiers. After selecting the softest natural feedwaters, such others as we may have to use should be chemically treated to reduce objectionable impurities to a minimum. A conservative estimate of the effect of scale $^1/_{16}$ in. thick on flues is to increase fuel consumption 10 per cent. The Hungarian State Railroads on 3000 locomotives use a mechanical feedwater purifier mounted on top of the boiler. The water on entering the purifier is subjected to full boiler pressure and temperature, and deposits its scale in and on this adjunct to the boiler, instead of in the boiler and on the flues. With reduction of scale there is a direct saving in fuel consumption, while a reduction in frequency of boiler washings saves considerable time and fuel. Without the purifier, locomotives washed on an average every five days required washing, with the purifier, every 54 days.

Lubrication. All journal bearings must be carefully lubricated to reduce friction; so must the center and side bearings of cars, the friction of which prevents the adjustment of trucks on entering and leaving curves, and thereby in the aggregate causes a heavy increase of the resistance to traction that the locomotive must overcome.

Wear on all wheels of locomotives, tenders, and cars must be watched. If the treads are worn hollow or the flanges vertical, the areas in contact with the rails when cars are oscillating or rounding curves will be increased and friction correspondingly increased. A heavy freight locomotive, tender, caboose, and 60 freight cars are carried on over 500 wheels; a slight increase in the friction on a few of them only would, in the aggregate, create a heavy drag on the locomotive.

Flange Lubrication. Flange lubrication reduces friction between rail and flanges, and therefore has a substantial effect in reducing fuel consumption. On two roads where flange lubrication was used, locomotive tires showed average miles between turnings of 33,000 and 44,000 miles, respectively, compared with 16,000 and 23,000 without. Wear on rails in curves shows a reduction of as high as 87 per cent. On one road of excessive curvature and grade, the life of locomotive tires was increased 375 per cent with flange lubrication.

Fuel Specifications. To insure full heat value the specifications for fuels purchased should cover their value in B.t.u.

Maximum Load in Vehicles. Freight cars should be fully loaded as far as may be. The resistance of a train of empty freight cars may run up to 8 lb. per ton; that of cars with average loads to 6 lb. per ton, while that of heavily loaded cars, of a total weight of 60 to 70 tons, may be as low as 4 lb. per ton. The load, in other words, should be carried in as few cars as possible.

Reduction of Dead Weight. As the expenditure of fuel in hauling a ton is the same whether or not it is paying freight, it is evident that the smaller the percentage of non-paying or dead weight to total weight moved, the smaller will be the cost of hauling the paying freight.

The United States Railroad Administration 50-ton single-sheathed box car weighs 47,200 lb. and the American Railway Association 50-ton box-car design, 42,400 lb., the excess weight of U.S.R.A. car being therefore 4800 lb. or 11.3 per cent. Based on 1923 data, the saving in fuel by eliminating this excess weight is $9.77 per car per year, or $4.10 per ton, which, capitalized at 5 per cent, shows that an initial expense of $82 in building a car is justified to reduce its weight one ton.

As far as practicable, all weight in a locomotive above what is needed for adhesion to develop traction should be eliminated.

Boiler design to suit class of service and character of fuel requires considerable flexibility in this principle.

Stimulation of Interest and Coöperation in Saving Fuel. Assuming that locomotives are properly maintained, in order to obtain the best results from burning fuel we must inspire the interest and secure the coöperation of the men on the footboards of 65,000 traveling power plants. How these are attained will appear from the following brief of the practice on a large system covering many states, and operated under the most varied topographical and climatic conditions.

1 In addition to inspection at each terminal of engines on arrival and again before departure to insure correction of all defects before the engine begins its trip, very thorough monthly inspections are made of all parts of the engines, boiler and appliances, draft arrangements, etc.

2 Classified statistics supply a complete history of operation. To be of most use they are issued immediately after the occurrences they record.

(*a*) A fuel bureau receives reports of train and locomotive movements within two days after movement. Ton-miles, fuel consumed per 1000 ton-miles, tons per train for each individual locomotive and each individual engineer and fireman are then computed, and the results put into superintendents' hands three to six days after movement, so shortcomings can be detected and quickly corrected.

(*b*) Monthly statements of individual performance of engineers, firemen, and locomotives are displayed on bulletin boards.

(*c*) A sheet recapitulating results by divisions is issue monthly.

3 On each division a fuel committee composed of 4 engineers, 4 firemen, 1 conductor, and 1 brakeman serves for six months and holds meetings bimonthly, the superintendent acting as chairman. The meetings are well advertised, and are attended by the superintendent's staff and employees from all related departments, who offer suggestions freely. Experts on operating methods and appliances deliver addresses. Motion pictures illustrating actual road conditions are exhibited. Minutes of meetings are widely distributed and published in employees' magazine.

4 To create emulation between divisions, a red silk banner is awarded quarterly to divisions showing greatest improvement in the previous year.

5 Gold-plated cap badges are awarded quarterly on each division to the engineer and fireman showing the best fuel record in through and local freight and passenger service.

6 Each superintendent publishes the names of five engineers and five firemen having the best fuel records for the month in through and local freight, passenger, and yard service on a roll of honor, which is posted in roundhouses and printed in the employees' magazine. A letter of commendation is sent to each man whose name appears on the roll.

7 The company sends yearly, at its expense, 38 men, consisting of an engineer and a fireman from each division with the best fuel records, as its representatives to the Annual Convention of the International Railway Fuel Association.

As a result of the policy described and of many fuel-saving devices, the company referred to moved 50 per cent more gross ton-miles per pound of fuel in 1924 than in 1913.

V—Transportation Department

About 20 per cent of all locomotive fuel is consumed when the locomotive is not doing useful work.

Avoidable losses of fuel used in firing up; losses from unconsumed fuel drawn from fireboxes, from blowing off and cooling down at end of runs; and losses incurred while waiting for water, sand, and other supplies on roundhouse tracks can be very greatly lessened by reducing the frequency of these occasions by lengthening locomotive runs. It is not uncommon now to run freight locomotives over two or three freight divisions, and passenger locomotives over four, before cooling them. The following are some examples of modern practice:

Passenger

Road	Runs 575 miles and over	Mileage
Southern Pacific	Los Angeles, Cal. to El Paso, Tex.	815
M. K. T.	Parsons, Kan. to San Antonio, Tex.	678
Union Pacific	Kansas City, Kan. to Denver, Colo.	640
Southern Pacific	San Antonio, Tex. to El Paso, Tex.	620
A. T. & S. F.	Winslow, Ariz. to Los Angeles, Cal.	602
Union Pacific	Denver, Colo. to Ogden, Utah	577
Southern Pacific	New Orleans, La. to San Antonio, Tex.	575

Freight

Road	Runs 350 miles and over	Mileage
Southern Pacific	El Paso, Tex. to Del Rio, Tex.	453
Southern Pacific	Sparks, Nev. to Carlin, Nev.	387
Southern Pacific	Houston, Tex. to Algiers, La.	362
Southern Pacific	San Antonio, Tex. to Fort Worth, Tex.	352

Four locomotives only are used on the Southern Pacific to haul passenger trains from New Orleans to San Francisco, a distance of 2490 miles.

Good despatching will reduce the number of needless stops, and careful planning will avoid fuel waste from locomotives standing in sidings because of poor meeting points, and from idle time at terminals waiting for trains.

To stop a freight train of 66 cars weighing with locomotive and tender 6,204,000 lb., moving at a speed of 40 miles per hour, and to restore that speed requires a consumption of 380 lb. of coal.

The economy of moving tonnage in as few cars and trains as possible and reduction of empty mileage is obvious.

Trend of Current and Future Economic Development. We now touch on a study of the trend of current and future economic development.

Much idle time and fuel can be saved by carefully designed engine terminal facilities, such as hot-water boiler-washing plants, well-located supply tracks, etc. and above all ample shops and modern tools to make repairs quickly.

Additional shops and tools provided at El Paso on the Southern Pacific Lines have reduced the average time in shops of locomotives 25 per cent, the effect of which is to add 33 per cent to the number of locomotives assigned to that division.

On a division operated with consolidation locomotives where water is exceptionally good, 16,000 lb. of fuel are saved per locomotive per annum by the installation of a hot-water boiler-washing plant.

Such improved facilities, while requiring large capital outlay, will increase the productive time of locomotives.

The burning of fuel in large terminals and shops should be centralized as far as practicable in order to eliminate machinery starting and stopping losses. Through free use of individual electric motors on large tools and groups of small tools, the waste of running long lines of shafting and of operating tools needlessly when but one or two on the line are used, can be eliminated and substantial economies can be effected in the 16,000,000 tons of fuel consumed on railroads in shops, stations, etc. Twenty per cent of the power in a large railroad shop was saved by eliminating steam-pipe losses and 13 per cent more by abandoning long lines of shafting and many belts through substituting electric for steam power. The changes represented a saving of $120,000 per year.

In locations where electrical energy can be purchased at lower cost than it can be produced by the railroad, opportunities for substantial fuel savings are presented.

The effect of all of the factors influencing increased work obtained out of fuel on a system of over 11,000 miles was to increase the ton-miles moved per pound of fuel 50 per cent from 1913 to 1924.

It is encouraging that the improvement in the work obtained from a pound of fuel is constant, but it is disappointing to reflect that we are indebted to European engineers for most of the improvements now in use on our locomotives. This is the case with the improved outside valve gear, superheaters, and feedwater heaters, some details of which, however, have been designed by American engineers; but nevertheless it is mortifying to admit that the principles underlying these devices were not first used in our country. The reason, of course, is that heretofore fuel has been so cheap and easily obtained with us that there was little inducement to pay much attention to its conservation; conditions have radically changed in the last few years, however.

The two principles affecting most profoundly the efficiency of stationary steam engines are compounding and condensing. Compounding alone may increase the efficiency of an engine 13 per cent, and condensing alone may increase it as much as 30 per cent; that is, condensing alone would increase the efficiency of fuel consumption of locomotives nearly as much as the brick arch, superheater, and feedwater heater combined, which we have already seen amounts to 34½ per cent. Compounding, which was used in the United States at one time very much more than now, will certainly come into use again; so that the combined effect of all the devices we have described, with compounding and condensing superadded, would be:

	Per cent
The brick arch when used has reduced fuel consumption to	91.0
The superheater when added has reduced it to	72.8
The feedwater heater when added, to	65.5
Using condensing engine may reduce it to	45.9
Compounding may reduce it to	39.9

Our European railroad brothers are fully alive to the advantages of using a condensing engine on the locomotive, as evidenced by descriptions published in the technical press in the past year or two.

Turbine Locomotives. The Swiss Federal Railways, says the *Railway Review*, of April 16, 1921, are testing a 10-wheel type locomotive with superheater, driven by a condensing steam turbine located on the locomotive frame in front of the smokebox. It is claimed that tests so far show a reduction of fuel consumption of 25 per cent compared with compound locomotives of usual construction, and very smooth running at high speeds on account of the reduction of heavy reciprocating parts.

The Swedish State Railway has built a turbine locomotive that was described in the same journal August 12, 1922. It is claimed that this locomotive, the Ljungström, shows a fuel consumption of about 50 per cent of that of a Pacific-type locomotive which it replaced.

The London and Northwestern Railroad has built an experimental locomotive driven by a condensing turbine which operates a generator, and the power is applied to the driving wheels through four electric motors of 275 hp. each.

Electric Locomotives. Where electric current can be generated from water power, trains can be moved very cheaply, but where the current is generated in a steam plant, the advantages are very much diminished.

Data given in United States Geological Survey Professional Paper No. 123 show that in eight large steam-electric plants studied in 1919, 12.2 per cent of the energy in coal is converted into electric energy; transmitting this electric energy to the motors of an electric locomotive reduces the available power to 9.9 per cent, and this is further reduced in the motors to 8.4 per cent of the total original energy in the coal. The corresponding efficiency of a modern steam locomotive with arches, superheater, and feedwater heater is 8.1 per cent under favorable conditions. While under existing conditions the advantage may be more than indicated in favor of the electric locomotive, the spread is hardly enough to tempt capital to assume the expenses of interest, depreciation, tax, and maintenance expenditures that would have to be incurred in changing from steam to electricity generated in a steam plant. The soundness of this conclusion was demonstrated by studies made of the Sierra Nevada and other heavy grades on the Southern Pacific, where trains on the former are lifted 6854 ft. in 86 miles. Assuming current generated in a steam station, the interest, taxes, and depreciation on additional net plant required were found to be more than three times as great as the estimated savings to be obtained from electric operation.

Other considerations such as smoke prevention and increasing capacity on heavy grades may influence the problem, but the speaker recalls no instance of a change being made solely to save fuel where a steam-generated current was used. The steam locomotive is by no means as obsolescent as its critics would have us believe. In an address published in the March, 1920, edition of the *Journal* of the American Institute of Electrical Engineers, a fuel consumption of 100 lb. per 1000 gross ton-miles by electric locomotives is given as applicable "to conditions universally obtaining on regular profiles." Data published by the Bureau of Railway Economics in September, 1921, show that the fuel consumption on 24,000 selected miles of steam railroad averaged but slightly over 100 lb. per 1000 ton-miles. Embraced in this mileage were the New York Central, Illinois Central, Chesapeake & Ohio, and St. Louis Southwestern. On 3142 miles, or 60 per cent of Southern Pacific main-line mileage, the fuel consumption in the same month was approximately 100 lb., while on the Salt Lake Division, 543 miles, the fuel record in October, 1921, averaged but 91 lb. per 1000 gross ton-miles for all locomotives. During the entire month of October, 1924, 62 Southern Pacific freight engineers held records of having moved 1000 gross ton-miles with a fuel consumption running between 48 and 59 lb. per 1000 ton-miles, under "conditions universally obtaining on regular profiles," or but little over half of what was considered a reasonable fuel consumption for electrically moved trains.

These are every-day performances, while we must remember that in the case of the Swedish experimental locomotive, and in records of electrically operated trains, the data relate either to experimental runs or to performance under exceptional conditions.

The performance of the modern steam locomotive in every-day service and without favorable stage setting is shown in the records of some American roads. On one of them, 26 superheated consolidation locomotives showed in daily service on a run with long grades of 21 ft. per mile an average consumption of 63½ lb. of coal per 1000 gross ton-miles, the range being from 55.8 to 71.7 lb.

Still more creditable to the steam locomotives and the men who drive them are the records of individual runners. Engineer A in two trips with trains of 2809 tons consumed 48.7 lb. per 1000 gross ton-miles; Engineer P in eight trips with trains of 2863 tons consumed 58.2 lb.; Engineer R in fourteen trips with trains of 2411 tons consumed 58.3 lb.

Internal-Combustion Engines. These engines vary widely in thermal efficiency and weights per unit, as shown in the table at the top of the next column.

Engines	Weight per brake horsepower, lb.	Brake thermal efficiency, per cent
Automobile	15	19.0
Diesel four-cycle	370	35.0
Diesel two-cycle	250	30.0
Airplane (Packard—recent press item)	1.04 lb. per hp.	

The use of the first type, except perhaps for short runs under exceptional conditions with light vehicles, is prohibitive on railroads, because although the automobile engine is two and one-third times as efficient as the steam locomotive, the present cost of its fuel is ten times as great.

The Diesel engine, however, shows the highest thermal efficiency of any known engine. We have seen that the most modern locomotive transforms but about 8.1 per cent of the heat energy of fuel into work; the Diesel, however, transforms 35 per cent, or over four times as much. Its fuel (crude oil, commonly called "Diesel oil") is not converted into gas as in gasoline engines, but is burned in the cylinder in the form of spray, and the expansive force of the products of combustion provides the motive power. Like the gas engine, however, it cannot start itself but must use some form of variable-speed transmission to start trains; the best way so far devised consists of electric transmission, but the combined engine and generator plants have proven so heavy as to bar its use for heavy traction. Because of its high thermal efficiency the Diesel engine offers opportunity to make great savings, and its future is very hopeful. A locomotive of this type now being built for the Southern Pacific by the Baldwin Locomotive Works seems to have overcome these handicaps and will soon be ready for trial.

The designs of an Italian Diesel locomotive show the following:

Weight in operation, approximately	117 tons
Tractive effort at 18½ m.p.h.	19,840 lb.

The locomotive is started by highly compressed air stored in tanks and fed to cylinders at each end of the locomotive, which run it until sufficient speed is attained to start the Diesel engines, when the compressed air is cut off. The air tanks are recharged by means of a connection with the main engines. The estimated fuel saving over a steam locomotive is 66⅔ per cent.

This design shows progress in adapting the Diesel engine to locomotives of serviceable commercial sizes, particularly in solving the problem of weight, as the weight of a steam locomotive and tender to develop about 20,000 lb. tractive effort is 150 tons.

The hope of the railroad executive for conserving fuel lies in:

1 Substituting hydroelectric current for steam, as our best steam locomotives can now fully equal the efficiency of electric locomotives using current generated in steam power stations.

2 Substituting compound condensing engines for the simple engines now used. From progress made in Europe, the solution of this problem appears encouraging.

3 The discovery of a cheap, high-gravity fuel that can be used in some such engine as is used on automobiles and airplanes.

4 Reduction of the weights of Diesel engines sufficiently to permit of their use as locomotive engines, and the development of a satisfactory variable-speed transmission which will weigh very much less than an electric generator and motor.

A Diesel-electric locomotive built in Germany for the Russian Government shows an overall efficiency between 21 per cent and 27.4 per cent. A steam locomotive tested at the same laboratory two days later averaged a total efficiency from 7.6 to 8.67 per cent. The fuel consumption of the Diesel-electric locomotive was about one-third that of the steam locomotive.

In a special report published in 1923, the National Industrial Conference Board appointed a committee to determine among other things:

1 Do the industries in the United States need more or fewer engineers than the number now being graduated from the engineering schools and colleges?

2 What kind of men do the industries require from the engineering schools and colleges, and what should be the nature of their education?

"The expansion of industry," says the report, "has been accompanied by vastly increased complexity of industrial operations, and the grouping of greater numbers of workers in corporate units has placed upon employers an increased social responsibility toward their employees, and toward the life and affairs of the community. All of these changes have created problems of human, social, and political relationships in which industry and society as a whole have become increasingly dependent upon trained technical and administrative leaders." Solutions to these problems have been sought

by railroad executives in the establishment of pensions for superannuated and incapacitated workers; in hospital departments, to furnish hospital service on the payment of nominal fees; by the establishment of group life-insurance plans whereby employees, regardless of age and without physical examination, receive the benefits of life insurance at approximately one-third the cost of the current commercial rates; and by the establishment of rest and reading rooms at terminals where no opportunities exist for relaxation after working hours.

The report also states that of the 41,600,000 persons who were gainfully employed in 1920, according to the United States census for that year, less than 4 per cent planned the activities and directed the energies of the whole working force. The same census figures show that since 1870 the number of administrators, supervisors, and technical experts has rapidly increased. In 1870 the number of persons engaged in administration and supervision was 170,000, or $1^1/_4$ per cent of those gainfully occupied. In 1890 the corresponding figure was 450,000, or 1.74 per cent, and in 1920, 1,510,000, or 3.6 per cent.

An examination of the personal records of the chairmen and presidents of the railroads of the United States show that in 1922, out of 32 chairmen, 11, or 34 per cent, had risen from the Engineering Department, and out of 171 presidents, 33, or 19 per cent, had risen from the ranks of engineers. Based as they are on data taken from census reports, the conclusions of the National Industrial Conference Board show increasing demands for the services of trained men, and furnish the most reliable and valuable information obtainable on the matters before us. As to schools, the report says:

> It is the business of the schools to train young men into fertile and exact thinkers, guided by common sense, who have a thorough knowledge of natural laws and of the means for u'ilizing natural forces for the advantage of man and the advancement of civilization. In other words, it is the business of engineering schools to produce, not finished engineers, but young men with a great capacity for becoming engineers, the goal being attained by the graduates only after years of development in the school of life.

Although a good technical expert may not develop into a good executive, nevertheless successful administrators should have certain characteristics, such as a good grasp of the fundamentals of science, the ability to think logically and quantitatively, exactness of method and power of analysis, the habit of looking forward, sound economic theories, an unlimited capacity to learn, pronounced firmness combined with a high sense of fairness and charity needed to control men, and the ability to write and speak clearly and correctly.

Mr. F. B. Jewett, vice-president of the American Telephone and Telegraph Company and president of the Bell Telephone Laboratories, Inc., expresses these views:

> The industry which I am connected with is a highly technical one which is based on physics and chemistry and mathematics; but so are many of the big industries in our country, and the more I see of them, the more convinced do I become that the directors of these industries in the future are going to be drawn more and more from men who have a thorough grounding in the fundamentals on which the industries are based. In the old days it was not so, but each day we go on now, it becomes more clearly apparent that because the industries are technical, because they are based on the fundamental science, they must be guided by men who have a thorough appreciation of the fundamentals, because business is hardly more than mixing the dollar or cents with physics and chemistry and mathematics. Since engineering schools are the place where we expect to turn out men who are going to guide technical industries, we should turn out men who know the principles of the fundamental sciences; who know the method of combining fundamental sciences with the dollar and cents' proposition, and know English in a way to enable them to express clearly what they know, so that others may profit by it; because it does none of us very much good to be ever so wise if we cannot express our ideas to others.
>
> It seems to me that if the engineering schools of the future are going to perform their function for the industries, they have got to get closer to the proposition of teaching and really inculcating the fundamentals. Let the matter of trying to make executives go, if you will. The men of executive ability will come to the fore in the general run of things, I think, provided the Lord gave them the right human traits, and provided they have a thorough grounding in the fundamentals.

Mr. E. M. Herr, president of the Westinghouse Electric and Manufacturing Company, says:

> I have been very much impressed with the discussion, and especially by the points brought out by the last speaker. I heartily endorse his view of the importance of the fundamentals, and of the idea of patient plodding in the minds of men who are going into industry. There is no royal road, to my mind, to a place of commanding importance in industry, or in any other business, and I do not believe that it is the function of educational institutions to try to teach young men to become captains of industry and administrators, or occupy very great and important executive positions.

Still another executive comments as follows:

> While there is general agreement on this view that one of the leading essentials in education in relation to industry is an adequate training in, and knowledge of, fundamentals, there is wide variation in the meaning of the term "fundamentals." From the point of view of the industrialist, the term "fundamentals" means not only a general groundwork of useful knowledge, but, more especially, a training in the power to use this knowledge in effective thought and action.
>
> The fundamentals of engineering training may be stated as follows:
>
> (*a*) Mathematics.
>
> (*b*) The important principles of physics (mechanics, heat, light, sound, electricity, magnetism), chemistry, biology and geology, the interrelations of natural phenomena and the application of these principles to practical problems.
>
> *c* The principles of economics and their application to industry and commerce.
>
> *d* The principles that govern the relations between people, not only as applied to managers and men, but also as applied to governments and society.
>
> *e* The history of nations.
>
> *f* The art of clear and correct expression in speaking, writing and drawing.
>
> The relative emphasis to be placed on each of these fundamentals is a matter to be determined for each engineering course.

In emphasizing the importance of training we must studiously avoid withering the aspirations and stifling the ambition of the large numbers of men in railroad and industrial service who have not had the benefit of overmuch school or any college preparation. These men outnumber vastly the high-school and college men, and to their credit be it said that the 65 per cent of chairmen and 81 per cent of presidents remaining after taking account of those that have risen from the ranks of engineers, have been drawn largely from the men who have had none of the benefits of higher education. Without mentioning them, the names of a number of the ablest and most distinguished railroad chairmen and presidents in the United States, who have by sheer ability and pluck risen from lowly ranks and have actually built their own careers and builded admirably well, suggest themselves.

Sympathetic guidance of both the college man and the non-college man presupposes a careful evaluation of the work of all employees and assurance to them that talent and effective work will be known to, and appreciated by, the management. Educators report a growing feeling among undergraduates that in most large corporations a young employee often is lost in a department, and for many months may not come under the observation of the leading men of the organization. A large public-utility company, the two largest manufacturers of electrical apparatus, and a few other large corporations which have unusual and enlightened personnel departments, in many cases are getting the pick of the young talent because of their attention to this problem.

These are some of the ways in which industry can supplement the work of the educators, and profiting by their example thus can we help those who are to "carry on" when we shall have passed.

The Economic Question of the Flettner Rotorship

COMMENTING upon the recent trip of the German rotorship *Buckau* to Scotland, the Association of German Seamen in Hamburg discussed the economic side of this new type of vessel. It was stated that no saving in the number of crew will result from the adoption of the Flettner rotorship, and that in the best case a saving will result only in the amount of fuel for the oil engine used in connection with the rotorship. Judging by the trial trip to Scotland there is a saving in fuel amounting to 30 per cent, which is equal to about $6.30 a day. The saving in fuel for a year with 90 days at sea would amount to $567, equal to $1^1/_2$ per cent of total operating cost. These savings, it is stated, will be offset by the high insurance rates charged by marine insurance companies for rotorships. Commenting further upon the fact that the rotor can be used effectively at a moderate wind velocity only, the association takes the view that the rotorship can not be employed to economic advantage.—*German Trade Reports and Opportunities*, Mar. 1, 1925, p. 33.

Performance of Centrifugal Fans for Electrical Machinery

By CARL J. FECHHEIMER,[1] EAST PITTSBURGH, PA.

The ordinary commercial centrifugal fan is provided with a stationary collecting device, generally a volute, which usually improves the performance materially. In the fans used in cooling electrical machinery, however, such collecting devices cannot be readily applied, and the revolving impeller therefore forms the sole means for developing the pressure needed to drive the air through the vent ducts. The present paper gives results of an extended series of tests recently made to determine the performance of centrifugal fans without collecting devices, and to obtain sufficient data to enable designers to select types of fans intelligently and to predict their performance.

IN direct-current electrical machines, the coils act as impellers for the air and additions are usually unnecessary for cooling. In enclosed machines, such as steam-turbine-driven generators, there are definite fans added near the ends of the rotor body. In such machines it is usually found that a collecting device cannot readily be applied, and the revolving impeller must be the sole means of driving the air through the vent ducts.

Our principal problem was to determine the performance of centrifugal fans without a collecting device, and to obtain data on the influence of the following independent variables:

1 Shapes of blades
2 Number of blades
3 Width of blades
4 Depth of blades
5 Influences of leakage paths with different kinds of blades
6 Influence of intake restrictions, and
7 Effects of certain external influences.

The Test Rig

The test rig, shown in Fig. 1, includes a wheel mounted on a suitable shaft supported in bearings at either side and driven by belt from an electric motor. This wheel rotates in a wooden box, at one end of which a chute is joined. After flowing the length of the chute the air turns through a right angle and is discharged upward, the outlet from the vertical duct being controlled by means of a horizontal door which is used as a valve.

To minimize leakage of air for most tests, a 1.5-in. by 1.5-in. angle iron was bent in a circle to form a flange ring, its external diameter (18 in.) corresponding with that of the fan. The horizontal part of this flange ring cleared a stationary ring by about $^1/_{16}$ in. In consequence the shaft could have the usual axial play in its bearings without much leakage through the $^1/_{16}$-in. clearance.

There are six air guides in the chute, three of which are vertical and the other three nearly horizontal. These air guides consist of flat sheet steel, one dimension of which is just a little less than the corresponding dimension of the chute, the other dimension being 12 in. One end of these steel sheets is pivoted. At the other end of the sheets, steel straps brought out through the wall of the chute afford a means of adjusting the guides without opening the chute, so that the air velocities are nearly uniform.

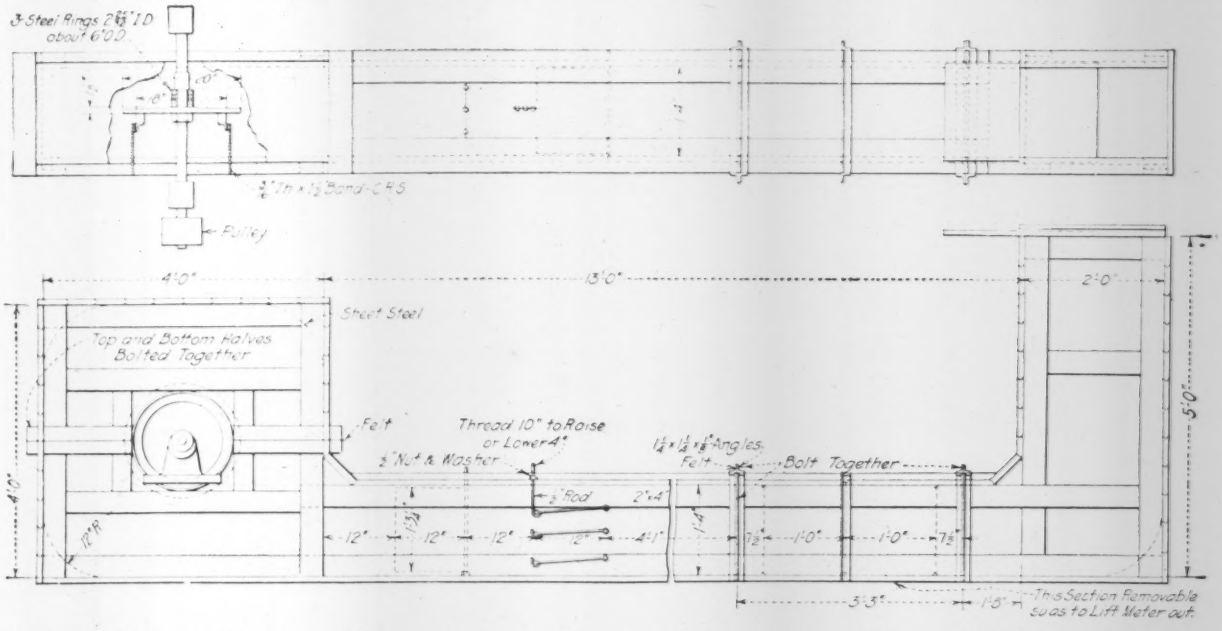


FIG. 1 PLAN AND ELEVATION OF EQUIPMENT USED IN TESTING CENTRIFUGAL FANS FOR COOLING ELECTRICAL MACHINERY

The Volume Meter

The meter as used was a modified form of the Thomas meter,[1] and consisted of a heater, which was placed at the central part of the section of the duct intended for the meter, and two sets of thermocouple junctions, one set about 12 in. in front of, and the other set the same distance behind, the heater. The heater wires were vertical to avoid sagging and short-circuiting, and were braced by means of a glass rod about half-way up.

A considerable error may be introduced with this type of volume meter if the velocities are materially different for different sections. If the sectional area of the duct be broken into a number of small, equal areas, then the ratio of the volume that would be measured

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Presented at the Spring Meeting, Cleveland, Ohio, May 26 to 29, 1924, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged.

[1] The principle of operation of the meter is that the heat developed electrically is picked up by the moving air streams, the temperature of the air being dependent upon (1) the mass per minute, (2) the number of heat units developed in the heater per minute, and (3) upon the specific heat of the air. In the meter developed by Prof. Carl Thomas the temperature rise of the air (or other gas) is measured by means of resistance exploring coils connected with other fixed external resistances in a Wheatstone-bridge network. For our particular work thermocouples were found to be preferable for measuring the air-temperature rise. The power input to the heater, measured electrically, gives the heat developed per unit time.

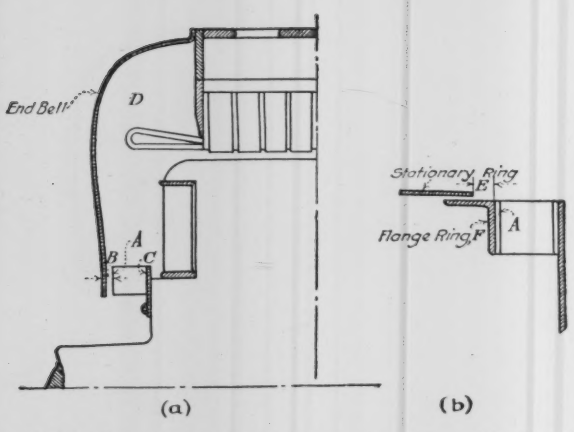

FIG. 2 METHODS OF APPLYING CENTRIFUGAL FANS TO ELECTRICAL MACHINERY

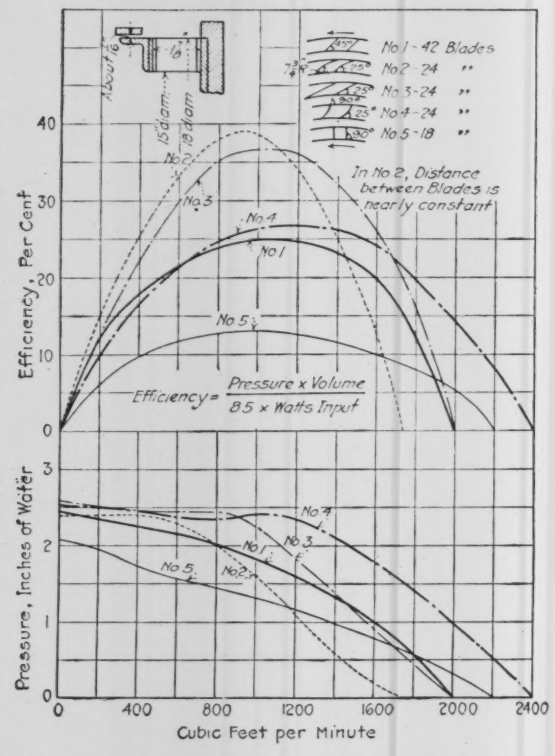
No 1 - 42 Blades
No 2 - 24 "
No 3 - 24 "
No 4 - 24 "
No 5 - 18 "
In No 2, Distance between Blades is nearly constant
Efficiency = Pressure x Volume / 8.5 x Watts Input
Efficiency, Per Cent
Pressure, Inches of Water
Cubic Feet per Minute

FIG. 3 PERFORMANCE CURVES OF FANS OF VARIOUS TYPES

(All fans have the same general dimensions and operated at 1800 r.p.m. with rotating shroud and flange rings; blade shapes were different, as shown. For performance curves with other numbers of blades, see Fig. 4.)

were the velocities uniform to the volume that is measured, is equal to:

$$R = \frac{(\Sigma V)\left(\Sigma \frac{1}{V}\right)}{n^2}$$

where V is the velocity considered uniform in any small area and n the number of small areas.

To determine the distribution of velocities in the duct, a pitot tube was used, and the air guides previously described were adjusted until the error due to non-uniformity of velocities was less than 1 per cent.

STATIC-PRESSURE MEASUREMENT

The air inside the box in which the fan rotated whirled around with the fan, the velocity of whirl decreasing as the radius increased. Consequently higher pressures were developed at the outer periphery of the box than near the fan; perhaps, too, a little of the velocity head was converted into pressure. If air near the inside of the wall of the box were trapped so as to be stationary and if the pressure of this trapped air were then measured, an accurate equivalent of the useful pressure in the end bell of an electrical machine would be obtained. Three curved pieces of sheet steel were put in the corners of the box shown in Fig. 1 principally for this purpose, there being enough leakage at the ends of these sheets axially to permit air to enter the "trap" back of the curved sheet and assume the same pressure as in the box near them. An air-tight connection between the trap and a manometer enabled the trap pressure to be measured.

To avoid errors due to pulsations and turbulence a special pressure gage was devised. This gage had a diaphragm about 0.01 in. in thickness which was flush with the inside surface of the upper wall of the duct. A "test indicator" such as is used for measuring small deflections and reading to 0.001 in. per division, had its plunger in contact with the upper side of the diaphragm. When the pressure in the duct is above that of the atmosphere, the

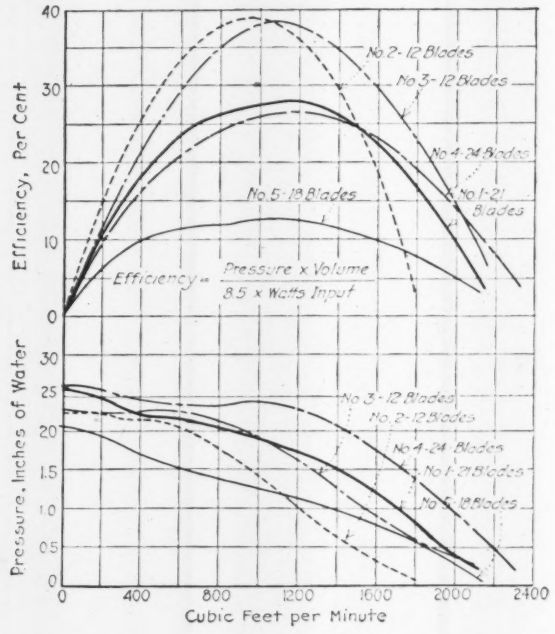
No 2 - 12 Blades
No 3 - 12 Blades
No 4 - 24 Blades
No 5 - 18 Blades
No 1 - 21 Blades
Efficiency = Pressure x Volume / 8.5 x Watts Input
Efficiency, Per Cent
Pressure, Inches of Water
Cubic Feet per Minute

FIG. 4 PERFORMANCE CURVES OF FANS OF VARIOUS TYPES

(See note under caption of Fig. 3 and sketches at top of that figure. For watts input, see Fig. 5. For performance with different number of blades, see Fig. 3.)

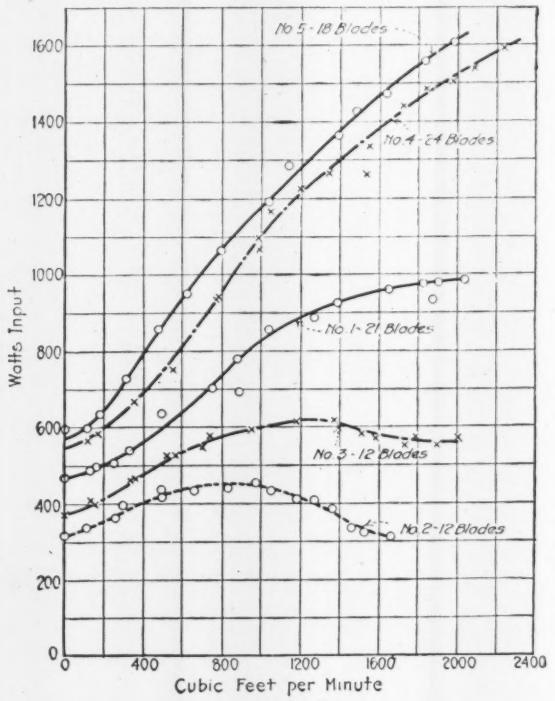

FIG. 5 WATTS INPUT OF VARIOUS TYPES OF FANS

(See note under caption of Fig. 3. For pressure-volume and efficiency curves, see Fig. 4.)

diaphragm moves upward and the needle of the gage deflects. A small hand pump is then used to increase the pressure in the small chamber above the diaphragm until the indicator reads the same as when no air flows. This in conjunction with a manometer results in a zero method of measurement, like a potentiometer.

POWER INPUT, OUTPUT, AND EFFICIENCY

A small motor of about 5 hp. capacity was belted to the fan and the input to this motor was measured in the usual way. The power output, neglecting the power represented by the velocity head multiplied by the volume, is:

$$\text{Horsepower} = \frac{\text{Pressure} \times \text{Volume}}{6350}$$

$$\text{Watts} = \frac{\text{Pressure} \times \text{Volume}}{8.51}$$

The pressure is the static pressure in inches of water column, and the volume is in cubic feet per minute.

The velocity head of the air stream after leaving the fan has been neglected because (1) it is impossible to evaluate the velocity head when a collecting device is not used, and (2) nearly all of the velocity head is destroyed, and only the static pressure must be relied upon to drive the air through the vent ducts.

RESULTS OF TESTS ON FANS

All fans were tested at 1800 r.p.m. and had the same external diameter of 18 in. Tests were classified as follows:

A—Internal Influences (the impeller only):

1 The shapes of the blades (Figs. 3, 4, 5, 12)
2 The number of blades (Figs. 6, 8, 9, 10, 13)
3 The width of the blades (Figs. 7, 19)
4 The depth of the blades (Figs. 6, 17, 18)
5 The use of a partition (Fig. 20).

B—External Influences:

1 Leakage paths, including omission of shrouds and rotating flange rings (Figs. 10, 11, 12, 14, 16, 18)
2 Stationary end windings (Fig. 15)

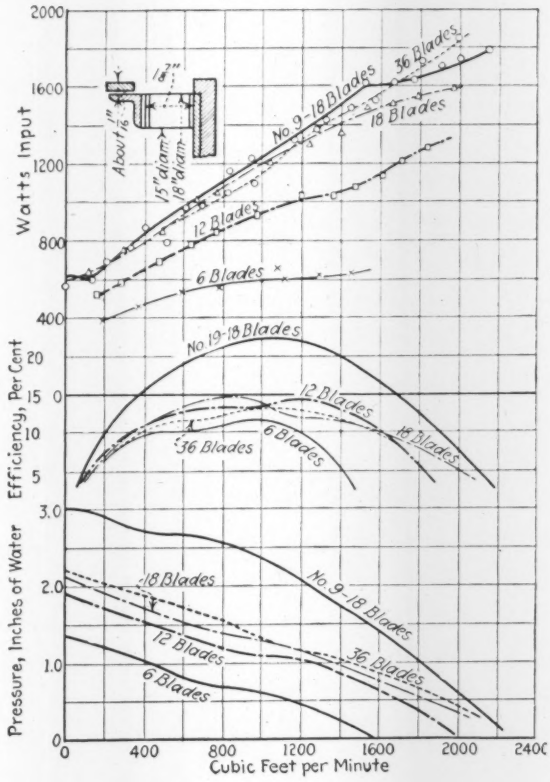

FIG. 6 PERFORMANCE CURVES OF VARIOUS FANS WITH RADIAL BLADES
(Fans operated at 1800 r.p.m. with rotating shroud and flange ring. All fans like sketch, except No. 9, for which internal diameter was 12 in.; otherwise like sketch.)

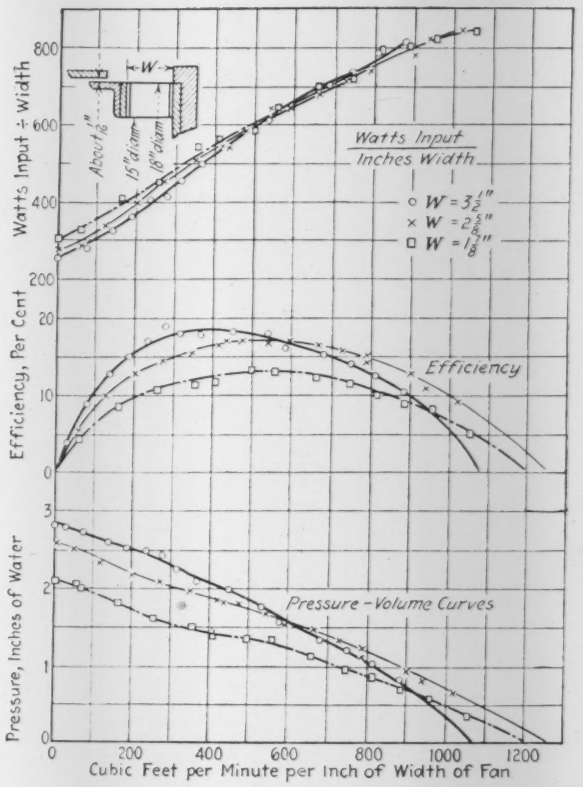

FIG. 7 CURVES SHOWING COMPARATIVE PERFORMANCE OF RADIAL-BLADE FANS OF VARIOUS WIDTHS
(All fans with 18 blades; speed in all cases, 1800 r.p.m.)

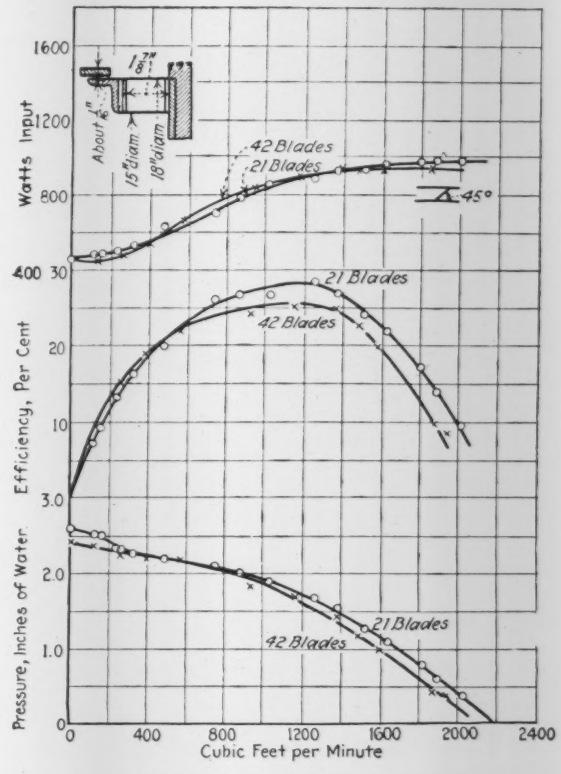

FIG. 8 PERFORMANCE CURVES OF FAN NO. 1
(Tested at 1800 r.p.m. with rotating shroud and flange ring.)

3 Diffuser and stationary guide vanes (Figs. 21, 22)
4 Intake restrictions (Figs. 23, 24, 25).

A1—*Shapes of Blades.* It was believed from theoretical considerations that about 25 deg. blade angle at entrance would be best for ratios of internal to external diameters between 0.8 and 0.85. Accordingly three fans were built with that angle (Figs. 3, 4, 5), one with curved blades terminating radially (No. 4), one

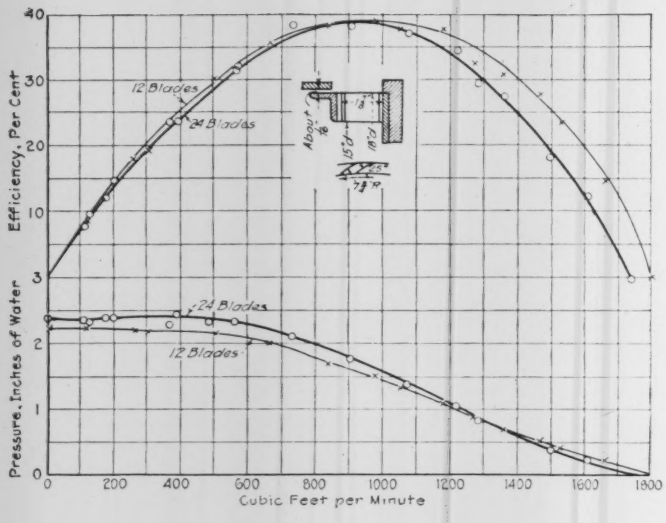

FIG. 9 PERFORMANCE CURVES OF FAN NO. 2
(Tested at 1800 r.p.m. with rotating shroud and flange ring. Distance between blades nearly uniform.)

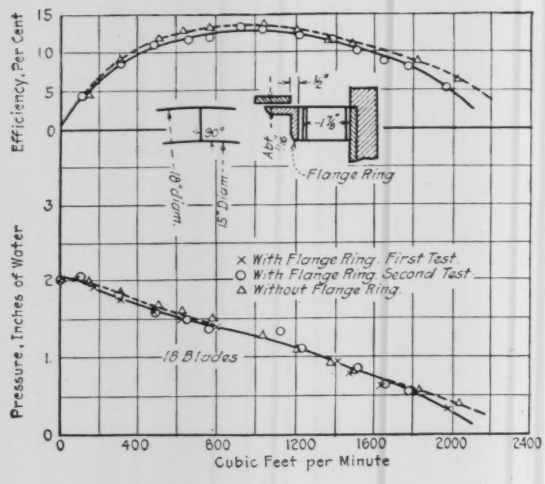

FIG. 11 PERFORMANCE CURVES OF FAN NO. 5
(Reduced to 1800 r.p.m.)

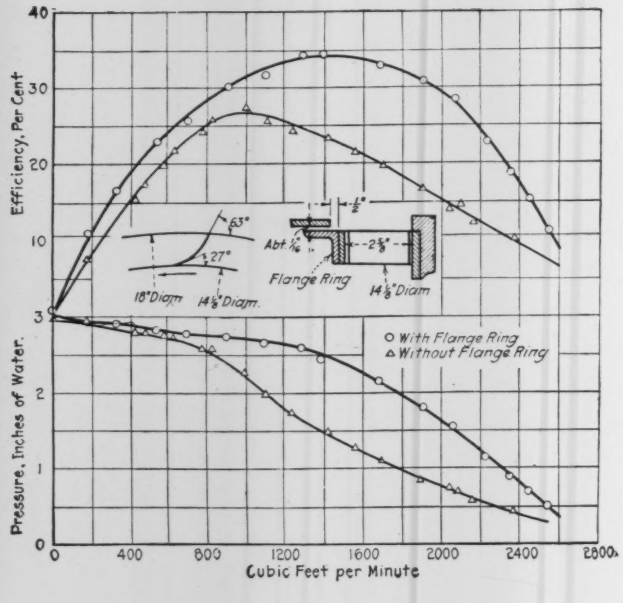

FIG. 12 PERFORMANCE CURVES OF FAN NO. 6A
(15 blades. Tested at 1800 r.p.m.)

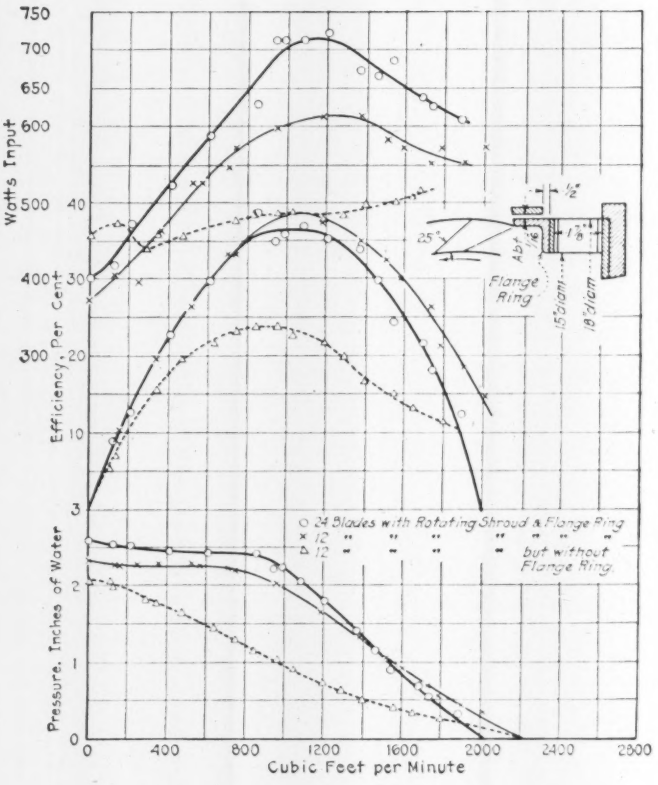
Watts Input
Efficiency, Per Cent
Pressure, Inches of Water
Flange Ring
15" Diam
18" Diam
○ 24 Blades with Rotating Shroud & Flange Ring
× 12 " " " " " " "
△ 12 " " " " but without Flange Ring.
Cubic Feet per Minute

FIG. 10 PERFORMANCE CURVES OF FAN NO. 3
(Tested at 1800 r.p.m.)

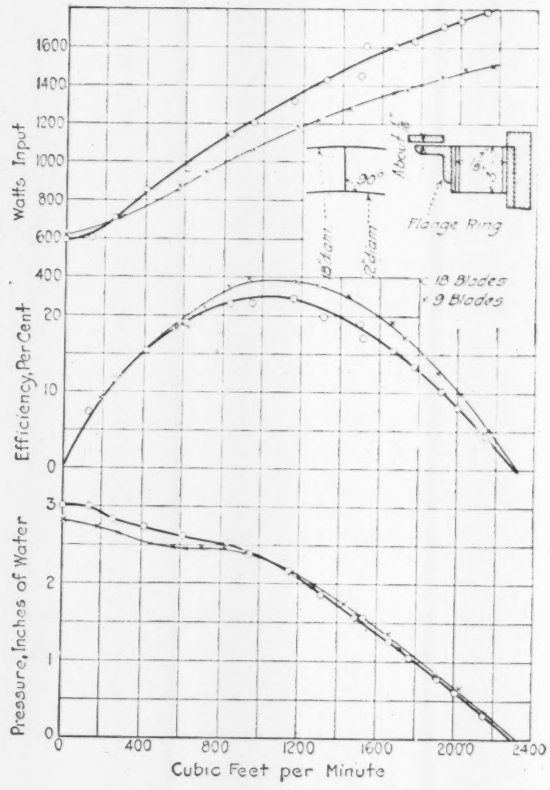

FIG. 13 PERFORMANCE CURVES OF FAN NO. 9
(Tested with rotating shroud and flange ring at 1800 r.p.m.)

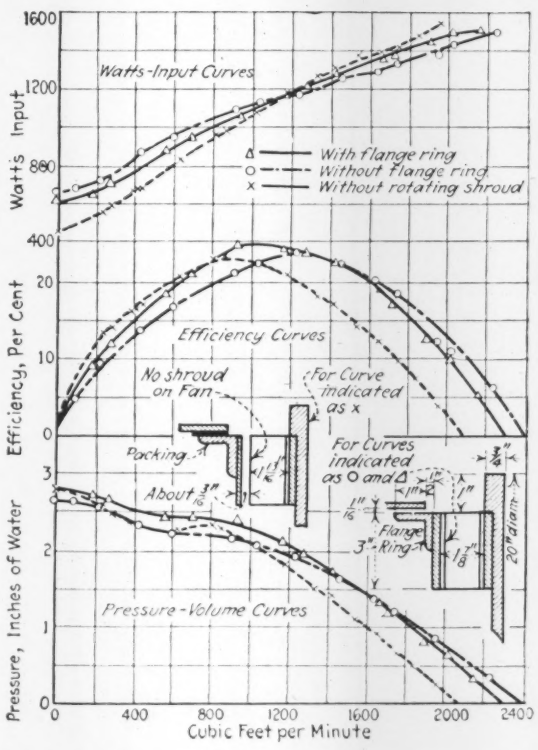

FIG. 14 PERFORMANCE CURVES OF FAN NO. 9
(9 blades, radial, tested at 1800 r.p.m.)

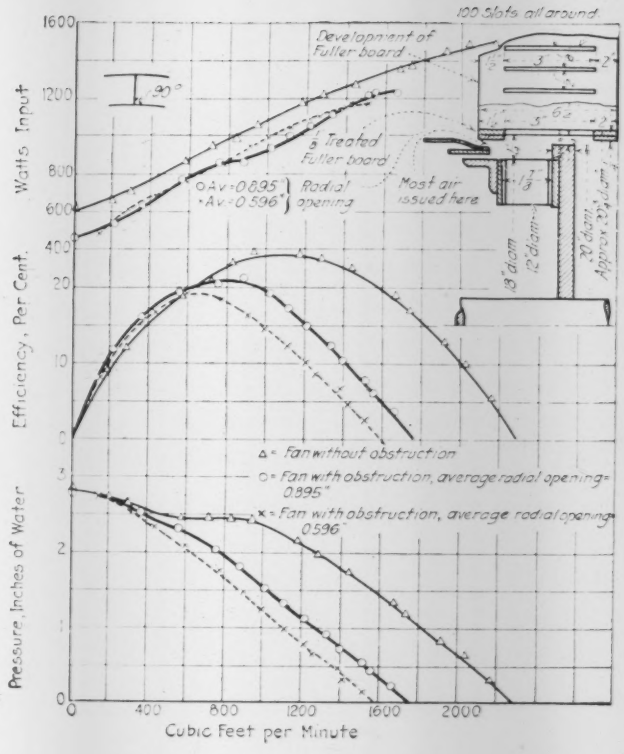
100 Slots all around
Development of Fuller board
Treated Fuller board
Most air issued here
Watts Input
Efficiency, Per Cent.
Δ = Fan without obstruction
O = Fan with obstruction, average radial opening = 0.895"
x = Fan with obstruction, average radial opening = 0.596"
Pressure, Inches of Water
Cubic Feet per Minute

FIG. 15 PERFORMANCE CURVES OF FAN NO. 9
(9 blades, 1800 r.p.m. To imitate obstruction offered by end windings.)

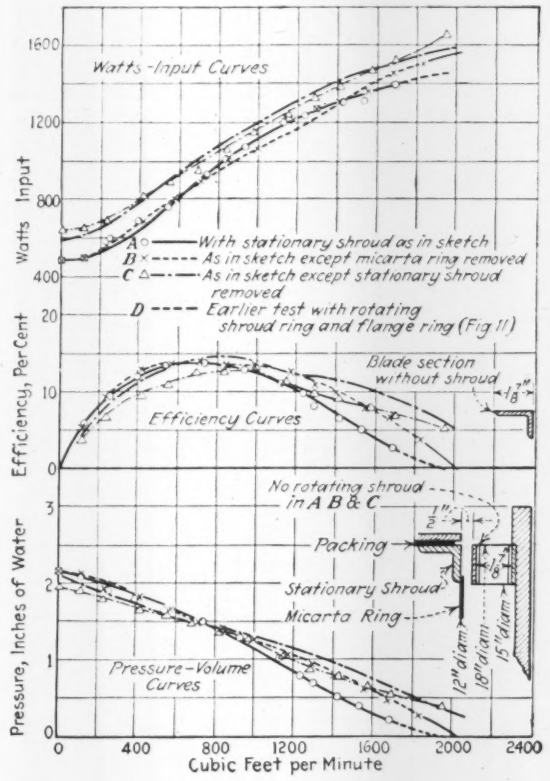
Watts-Input Curves
Watts Input
A With stationary shroud as in sketch
B As in sketch except micarta ring removed
C As in sketch except stationary shroud removed
D Earlier test with rotating shroud ring and flange ring (Fig 11)
Efficiency Curves
Efficiency, Per Cent
Blade section without shroud
No rotating shroud in A B & C
Packing
Stationary Shroud
Micarta Ring
Pressure-Volume Curves
12" diam.
18" diam.
15" diam.
Pressure, Inches of Water
Cubic Feet per Minute

FIG. 16 TESTS TO DETERMINE EFFECT OF SHROUD RINGS
[All tests on Fan No. 5 (18 radial blades) at 1800 r.p.m.]

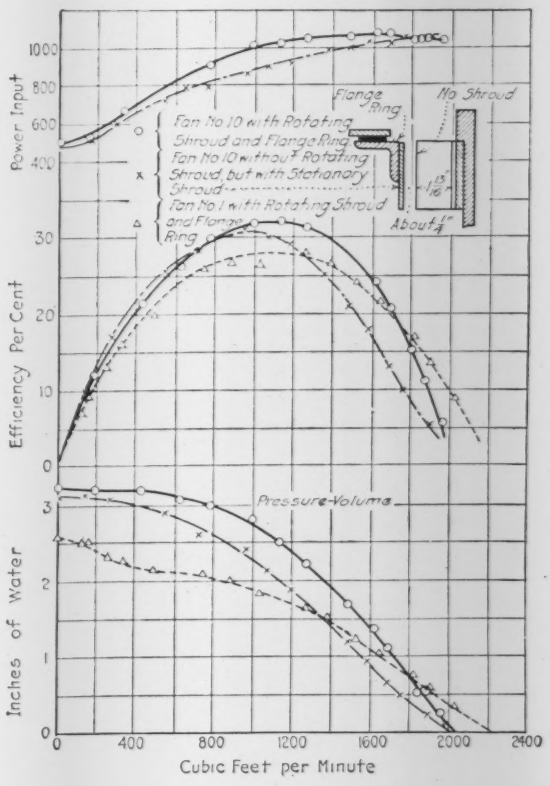
Flange Ring
No Shroud
Fan No 10 with Rotating Shroud and Flange Ring
Fan No 10 without Rotating Shroud, but with Stationary Shroud
Fan No 1 with Rotating Shroud and Flange Ring
About 1/4"
Power Input
Efficiency Per Cent
Pressure-Volume
Inches of Water
Cubic Feet per Minute

FIG. 17 PERFORMANCE CURVES OF FANS NOS. 1 AND 10
(Both fans 18 in. in external diameter with straight blades inclined at 45 deg. to tangent at inner periphery. Fan No. 1 has 21 blades; fan No. 10, 12 blades. Internal diameters: Fan No. 1, 15 in.; fan No. 10, 12 in.)

with curved-back blades with substantially uniform section between blades (No. 2), and one with straight blades (No. 3). Fans with a 45-deg. entrance angle have frequently been built for use in electrical machinery, and therefore that type was also tested (No. 1). Inasmuch as radial blades must be used for machines that operate in either direction of rotation, that type was also made (No. 5). The performance of another curved-blade fan which was built to check the performance on a fan previously built for a turbo-alternator, will be found in Fig. 12. With the exception of the curves on Fig. 12, all data on the other curve sheets (Figs. 3, 4, 5) pertain to fans of the same dimensions (18 in. external diameter, 15 in. internal diameter, 1.875 in. wide) and operated under identical conditions. The only difference between Figs. 3 and 4 is in the number of blades, and in Fig. 5 the watts input are plotted for the smaller number of blades as in Fig. 4.

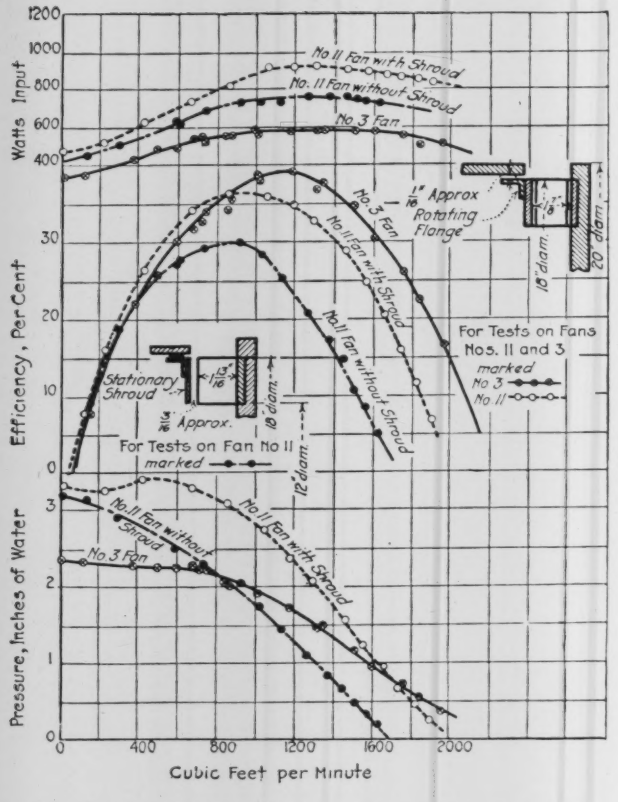
Watts Input
Efficiency, Per Cent
Pressure, Inches of Water
Cubic Feet per Minute
No. 11 Fan with Shroud
No. 11 Fan without Shroud
No. 3 Fan
1" Approx Rotating Flange
Stationary Shroud
For Tests on Fans Nos. 11 and 3 marked
For Tests on Fan No 11 marked

FIG. 18 PERFORMANCE CURVES OF FANS NOS. 3 AND 11

(Both fans have 12 straight blades inclined at 25 deg. to tangent at inner periphery. Internal diameter of fan No. 3, 15 in.; of fan No. 11, 12 in. All tests at 1800 r.p.m. Note that curves of fan No. 3 differ slightly from earlier tests in other figures. "Without shroud" means without rotating but with stationary shroud, as in sketch.)

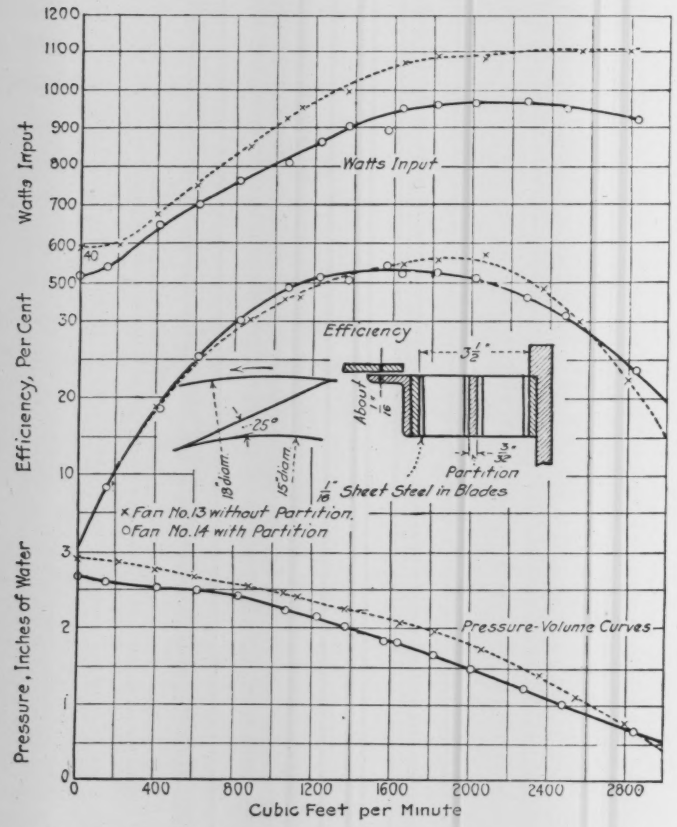

FIG. 20 PERFORMANCE CURVES OF FANS NOS. 13 AND 14, SHOWING INFLUENCE OF PARTITION

(Blades spaced 1/12 of circle in both fans. All tests at 1800 r.p.m.)

The differences in performance for the five fans are indeed remarkable. It will be seen from Figs. 3 and 4 that No. 2 fan gives maximum efficiency in accordance with theoretical considerations. However the restricted area between blades decreases the maximum volume. No. 3 fan with straight blades but with the same entrance angle as No. 2 has nearly as high maximum efficiency, and delivers a larger volume of air for a given pressure. There is a material improvement in the efficiency of 25-deg. straight-blade fans over 45-deg. fans. An idea of the increase in efficiency obtained by changing the entrance angle from 90 deg. to 25 deg. and curving the blade will be seen from an inspection of curves for fan No. 4, Fig. 3.

With reference to blade shape as affecting the power input, the family of curves in Fig. 5 is especially interesting. The rapid increase in power consumption with volume of delivery is well

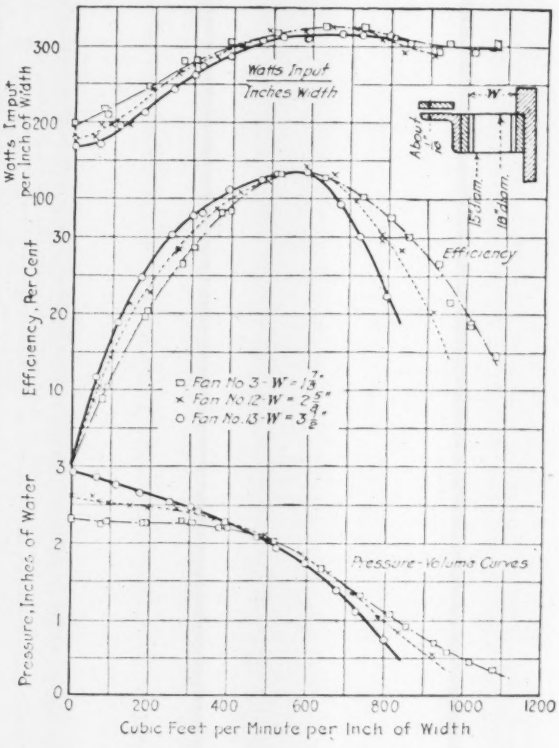
Watts Input per Inch of Width
Efficiency, Per Cent
Pressure, Inches of Water
Cubic Feet per Minute per Inch of Width
Watts Input / Inches Width
Efficiency
Pressure-Volume Curves

FIG. 19 CURVES SHOWING COMPARATIVE PERFORMANCE OF INCLINED-BLADE FANS OF VARIOUS WIDTHS

(All fans have 12 straight blades inclined at 25 deg. to tangent at inner periphery. All tests at 1800 r.p.m.)

known for radial-blade fans and many other shapes. The power curve for a fan with small entrance shock loss but large loss at exit (No. 4) is of much the same shape. But with the backwardly curved blades (No. 2) the power consumption rises to a maximum and then falls, there being about the same input for maximum volume as for zero volume. A somewhat similar condition of reaching a maximum and then falling slightly holds for straight blades with the same entrance angle (No. 3). This curve is especially interesting because the power input is nearly constant over what might be considered to be working range (Fig. 5).

A2—*Number of Blades.* The surprisingly small gain by the use of a large number of blades is particularly evident; in fact, in many of the fans the performance is better with the smaller number.

A3—*Widths of Blades.* With a large discharge area the volume may not be proportional to the width, as the air distribution axially becomes less uniform as the width is increased, thereby giving rise to non-uniform velocities between blades. The greater pressure developed with the wide fan tends to offset this somewhat, but it has been found that the maximum volume per inch of width may decrease as the fan is widened; there being one width of fan for which the volume (at zero pressure) per inch of width is a maximum.

Between the points of zero volume and zero pressure the volume and pressure must necessarily be affected by the eddies and the greater developed pressure with increased width, one tending to offset the other, the result being that if the volumes per inch of width be plotted as abscissas, the pressures are highest for the

widest fans (for the low volumes); and there are definite widths which give the highest pressures at the large volumes, neither the very narrow nor the very wide fans giving the large pressures at the large volumes.

As the width is increased the volume is increased nearly in proportion, and the area of inlet (between, say, the inner diameter of the impeller and the shaft) remains constant. Consequently the velocity through this section increases with the fan width, and as this is accompanied by a loss of head proportional to the

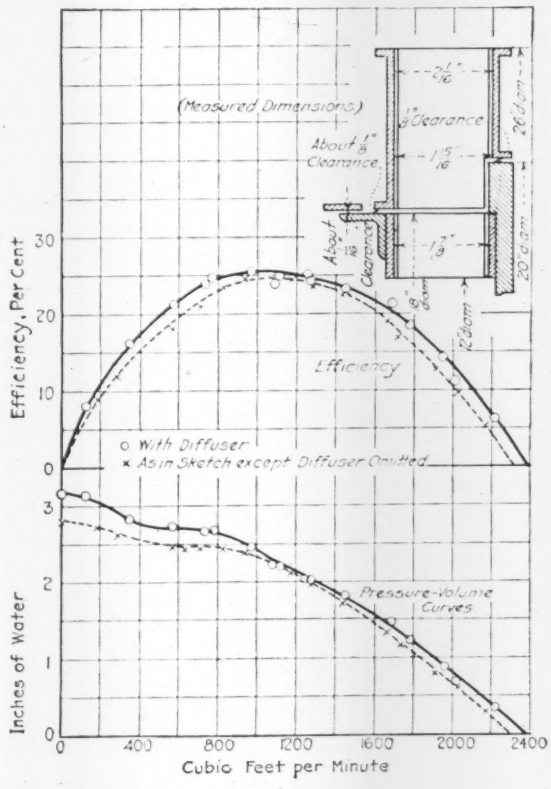

FIG. 21 PERFORMANCE CURVES OF FAN NO. 9, SHOWING INFLUENCE OF DIFFUSER
(9 radial blades; r.p.m., 1800.)

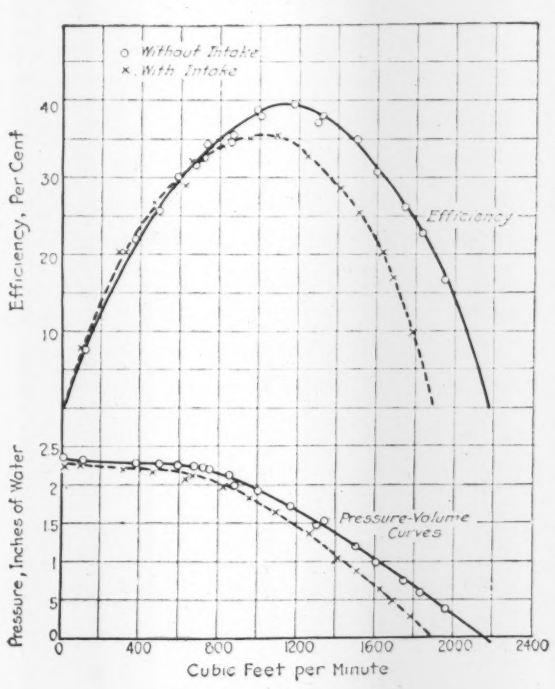

FIG. 23 PERFORMANCE CURVES OF FAN NO. 3, SHOWING INFLUENCE OF INTAKE
(Fan has 12 straight blades inclined at 25 deg. to tangent. External and internal diameters 18 in. and 15 in., respectively; r.p.m., 1800. Intake shown in Fig. 25.)

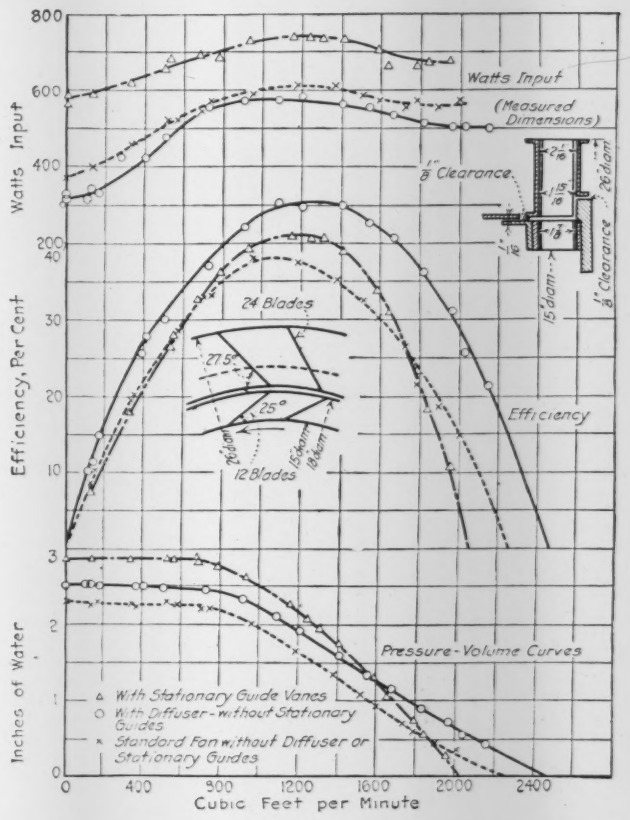

FIG. 22 PERFORMANCE CURVES OF FAN NO. 3, SHOWING INFLUENCE OF DIFFUSER AND STATIONARY GUIDE VANES
(Diffuser tests taken first, after which stationary guides were added.)

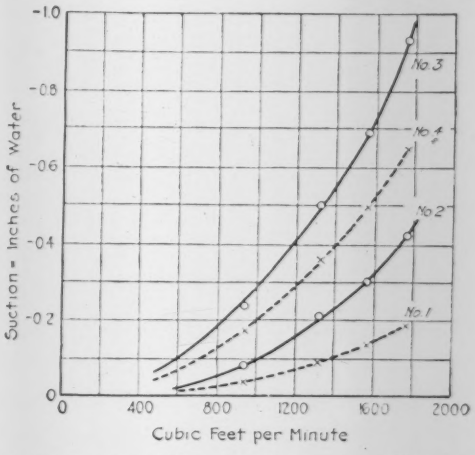

FIG. 24 CURVES SHOWING PRESSURE (SUCTION) AT VARIOUS POSITIONS OF INTAKE TO FAN FOR VARIOUS VOLUMES
(See Figs. 23 and 25. Numbers on curves refer to positions in intake given in Fig. 25.)

square of the velocity, there is a limit imposed beyond which the fan width should not be increased.

A4—*Depth of Blades.* The improvement in efficiency with the deep blades is particularly marked in the curves of Fig. 6. For a comparison of performances with deep and shallow blades for 45-deg.-inclined blades see Fig. 17, the conditions of test being the same for the curves indicated by the small circles and triangles. The change in performance of the 25-deg. straight-blade fan due to change in depth will readily be seen from an inspection of Fig. 18. There is, with the deeper 25-deg. blades, an increase in pressure at small volumes, a slight decrease in volume at low pressures, and a decrease in maximum efficiency. It would seem that the shock loss at entrance is increased by deepening the 25-deg. blades but is decreased with radial blades.

A5—*Partition.* In general a partition is used only to reduce the stresses in the blades. Only one test was made to determine its influence upon the performance (Fig. 20). In this case the 25-deg.

straight-blade fans were the ones investigated. At low volumes the pressure is reduced due to the reduction in effective depth of whirl. Furthermore the partition reduces the sectional area through which the air flows, and that combined with the reduced pressure (at least at small volumes) reduces the volume. However, the curves cross at the higher volumes, showing that the partition reduces the eddying between blades. In general, it would seem that the partition is detrimental to the performance.

B1—*Influence of Leakage Paths.* In applying centrifugal fans to electrical machinery, as illustrated in Fig. 2, the construction is often considerably simplified by omitting a rotating shroud ring (Figs. 2a and 2b).

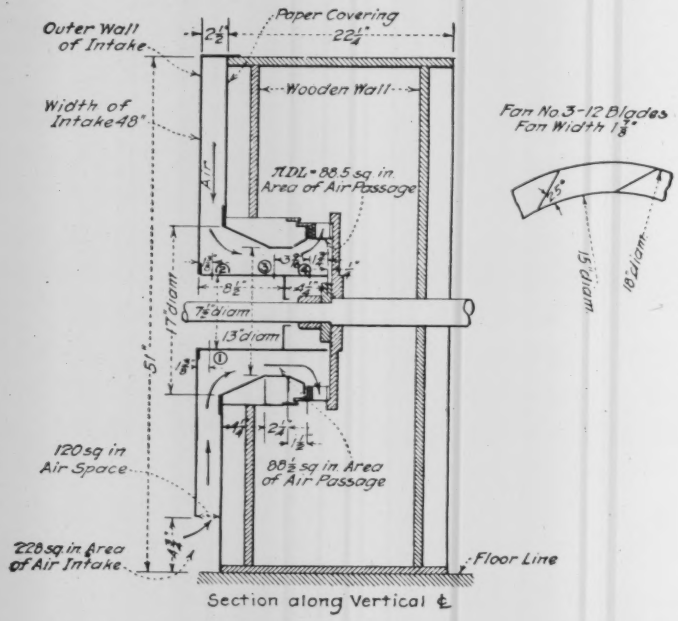

FIG. 25 VERTICAL SECTION OF FAN, CASING, AND INTAKE
(Positions for pressure readings indicated by numbers in circles. See Fig. 24.)

With or without a rotating shroud, if there is a certain clearance between the fan blade and the stationary shroud, air is lost through this clearance. In the curves various test results showing the influence of leakage are given.[1]

Although tests were made on radial-blade fans of several numbers and widths, with and without the flange ring, to determine the influence of leakage through the space which had been occupied by it, only the tests on the 1⅞-in.-wide 18-blade fan are given here. In all cases the results showed but little change due to the removal of the flange ring. Generally, the volume was increased when the flange ring was removed for the low-pressure parts of the curves.

B2—*Influence of End Windings.* In induction motors in which the clearance between stator bore and rotor is small and the coil ends may not be flared back very much, the obstruction offered by the coil ends may not be negligible. The end-winding obstruction was imitated by cutting ⅛-in. slots in a sheet of fullerboard placed around the test fan. Between slots, solid spaces ½ in. wide imitated the coil ends. Obstructions were further placed in the path of the air axially to imitate the rings used for supporting the coil ends (see Fig. 15). Two sets of tests were made with two different ratio clearances (at one end only) to imitate two different backward flares of the coil ends. All of the tests are plotted in Fig. 15.

B3—*Diffuser and Stationary Guide Vanes.* Tests were made on the deep-radial-blade fan with diffuser; and on the fan having shallow blades inclined 25 deg. both with diffuser and with stationary guides. (See Figs. 21 and 22.) With both fans there is a gain in pressure and efficiency due to employing the diffuser, but it is considerably greater with the inclined-blade fan than with the one having radial blades. With the inclined blades the pressure at zero volume was increased 10 per cent, the volume at zero pressure 12 per cent, and the maximum efficiency from 38 to 45.5 per cent. The curves with and without diffuser have the same general shape. In order to obtain much of a gain by means of a diffuser the latter should be fairly deep radially. When vanes were fitted into the diffuser which had previously been used (see Fig. 22), the pressure at low volumes was increased by means of the vanes to values appreciably higher than those with the diffuser alone.

B4—*Influence of Intake Restrictions.* When centrifugal fans are used for cooling turbo-alternators, it is customary to provide a suitable intake to which external ducts may be connected if desired. When such an intake is used, the entrance for the air is usually near the floor line, the air then passing vertically upward and some of it being turned through 180 deg. before it enters the fan. There is usually a restricted section shortly before entrance to the fan, but in most cases the area of the section is not less than the area represented by the internal periphery of the fan multiplied by the width.

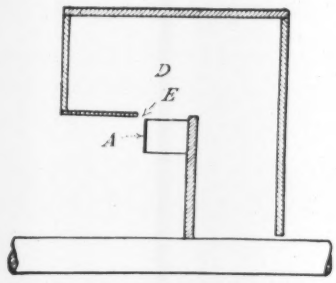

FIG. 26 SECTION OF RADIAL-BLADE FAN WITHOUT FLANGE RING

The test rig which was used for obtaining the curves was modified so as to simulate the intake conditions for a turbo-generator. A vertical section of the fan, the casing about it, and the intake is shown in Fig. 25. The cylinder near the center of the outside cover was used to restrict the section before the air entered in the fan.

An inspection of the pressure-volume curve, Fig. 23, shows that the pressure drop due to the intake is approximately proportional to the square of the volume, as would be expected. There is, of course, a corresponding reduction in efficiency due to the loss of pressure.

[1] Other tests to determine influence of leakage with radial blades were made, but are not published. Results were similar to those in curves in Fig. 10.

Measurement of Pipe Flow by the Coördinate Method

THE determination of the discharge capacity of an open pipe from measurements taken of the coördinates of the upper surface curve of the jet is not new. In view of the scanty data available on this subject, the results of some experiments recently performed at Purdue University become of interest and the original article shows the apparatus used and the method of calculation. As a result of their work the experimenters proposed the use of the following equation for the flow from any of the pipes tested: $q = d^{2.56}k^{1.82}$, where q is the discharge from the pipe in cubic feet per minute; d, the diameter of the pipe in inches; and $k = (d - y)/d$ is the ratio of depth. This equation applies for values of k between 0.2 and 0.65 only, for when k is much less than 0.2 the stream does not spring clear, and the law of flow is different; also, above k = 0.65 the pipe is not partly filled for its entire length but on the contrary is entirely filled with the exception of a small distance from the end, and this condition changes the hydraulic ratios and modifies the law of flow. (F. W. Greve and Maurice J. Zucrow, respectively Asst. Prof. of Hydraulic Engineering and Research Asst., Engineering Experiment Station, Purdue University, Lafayette, Ind., in *Journal of the American Waterworks Association*, vol. 13, no. 3, Mar. 1925, pp. 306–311, 3 figs., 4 tables, *e*)

Bricks from Ashes

IN A LECTURE delivered at the Huddersfield Technical College, W. H. Casmey called attention to a process of manufacturing bricks from furnace clinker and ashes. These waste materials are roughly ground and mixed with a definite proportion of lime and water. The material is then molded, piled on small cars, and run into a steam chamber some 60 ft. long by 6 ft. 6 in. in diameter. When the chamber is fully charged it is hermetically closed and steam at a pressure of 120 lb. per sq. in. is admitted, the bricks being kept under this pressure for about six hours. When cooled they are ready for immediate use. There has not been sufficiently long experience with these bricks to determine their durability. (*The Chemical Age*, vol. 12, no. 299, March 7, 1925, p. 220, *g*)

Temperatures of Evaporation of Water into Air

A Report of Experiments Made to Determine the Laws Governing the Deviation of The Actual Temperature of Evaporation from the Theoretical

By W. H. CARRIER[1] AND D. C. LINDSAY,[2] NEWARK, N. J.

IT WAS first shown in the paper entitled Rational Psychrometric Formulas,[3] presented before the Society at the Annual Meeting of 1911, that a fundamental equation of heat balance may be established between any evaporating liquid and the surrounding atmosphere, and that eventually a constant equilibrium temperature is reached, which can be altered only by changing the total-heat relation between the liquid and the atmosphere. This equilibrium temperature, commonly termed the "wet-bulb temperature," is determinable by a thermometer, the bulb of which is kept wet by the evaporating liquid. The wet-bulb temperature throws a very interesting light on the fundamental laws involved in all commercial evaporative processes, and the effect of the wet-bulb temperature upon human physical comfort has a great popular interest.

The experimental data herein presented prove conclusively that the temperature of evaporation is not indeterminate, but has a very definite limit which in practical application is very closely approximated and which is dependent upon the ultimate equilibrium of heat conditions.

Although it has been recognized that observations of wet-bulb temperatures are in error with respect to the theoretical temperature of equilibrium, exact data as to the amount of this error and its variation relative to temperature and effective velocities of air have heretofore been only approximated to. During the past four years the authors have conducted exhaustive experiments with special equipment at Cornell University and at the Case School of Applied Science. The purpose of the experiments has been, first, to show that under ideal conditions permitting true adiabatic saturation, i.e., maintaining a constant total-heat relation during saturation, the wet-bulb temperature is actually the temperature of equilibrium represented in the heat-equilibrium equation; and secondly, to show how, and to what extent, the wet-bulb temperature, observed under ordinary conditions, varies from the theoretical equilibrium temperature.

The Equations of Heat Balance and Relative Rates of Diffusion

Of two general methods which have been proposed for the study of laws underlying the equilibrium temperature in an evaporating liquid which obtains its heat of vaporization from the surrounding atmosphere alone, the first involves the equation expressing the increase in the heat of vaporization as equal to the decrease in the sensible heat of the atmosphere from which the heat is extracted. This equation of heat balance is:

Latent heat absorbed = Sensible heat lost

or

$$r'(w' - w) = (C_{pa} + C_{ps}w)\,(t - t') \quad \ldots\ldots [1]$$

where

r' = latent heat of vaporization per unit weight of vapor at the resultant temperature t'
w' = final weight of vapor per unit weight of gas into which the liquid is evaporating
w = initial weight of vapor per unit weight of gas
C_{pa} = mean specific heat of the gas between temperatures $(t - t')$
C_{ps} = mean specific heat of the vapor between temperatures $(t - t')$
t = initial temperature of the gas
t' = final temperature of the gas, vapor, and liquid.

From this the theoretical temperature of equilibrium may be definitely located if the initial temperature and moisture content and the final moisture content of the gas are known.

The second method analyzes the rates of heat flow—the sensible heat flow to the wet bulb from the surrounding atmosphere—due to temperature difference, and the corresponding rate of outward heat flow, due to the evaporation of the liquid and its diffusion into the surrounding atmosphere.

Equations expressing the balance of rates of flow are:

Rate of moisture diffusion from unit area of liquid surface per unit time:

$$\frac{dw}{A\,d\theta} = k'(e' - e) \quad \ldots\ldots [2]$$

where

dw = weight of liquid evaporated per unit time $d\theta$
A = area of evaporating surface
k' = coefficient of moisture diffusion per unit difference in vapor pressure of liquid and vapor pressure in the atmosphere
e' = vapor pressure of liquid
e = vapor pressure in atmosphere.

Rate of heat diffusion through film to liquid surface:

$$\frac{dq}{A\,d\theta} = h(t - t') \quad \ldots\ldots [3]$$

where

dq = heat diffused per unit time $d\theta$
A = area of surface
h = coefficient of heat diffusion per degree difference in temperature of liquid and atmosphere

But $dq = r'dw$, where r' = latent heat of vaporization corresponding to temperature t'; therefore

$$\frac{dw}{A\,d\theta} = \frac{h}{r'}(t - t')$$

and

$$(e' - e) = \frac{h}{k'r'}(t - t') \quad \ldots\ldots [4]$$

According to the law of gaseous mixtures the weights of the two component parts of a mixture are in proportion to the products of their respective pressures and their specific weights. So in a mixture of water vapor and air:

$$w = \frac{Se}{P - e}$$

where w = weight of moisture per pound of air
S = specific weight of water vapor compared with air
e = vapor pressure
P = barometric or total pressure of the mixture.

$$e = \frac{Pw}{S + w}$$

Substituting for e in Equation [4],

$$\frac{Pw'}{S + w'} - \frac{Pw}{S + w} = \frac{h}{k'r'}(t - t')$$

At temperatures below 150 deg. fahr. where w and w' are small, this equation may be written

$$\frac{P}{S + w}(w' - w) = \frac{h}{k'r'}(t - t')$$

$$r'(w' - w) = \frac{h}{k}(t - t') \quad \ldots\ldots [5]$$

where $k = k'P/(S + w)$.

[1] President, Carrier Engineering Corporation, Newark, N. J. Mem. A.S.M.E.
[2] Physicist, Carrier Engineering Corporation.
[3] Trans. A.S.M.E., vol. 33 (1911), p. 1005.

Presented at the Annual Meeting, New York, December 1 to 4, 1924, of The American Society of Mechanical Engineers. Abridged.

By comparing Equations [1] and [5] established by the two methods presented, it will be seen that the two equations are of the same form and that h/k must be theoretically equivalent to $(C_{pa} + C_{ps}w)$ which is the specific heat of the initial mixture of gas and vapor. The experimental deviation of the observed wet-bulb temperature from the equilibrium temperature as given in Equation [1], is apparently accounted for as follows:

1 Incomplete saturation in the film immediately in contact with the wet surface; in other words an inward flow of *sensible* heat, from the atmosphere, greater than the outward flow of *latent* heat from the liquid at the theoretical temperature of equilibrium

2 By direct radiation from surrounding objects which are normally at the temperature of the atmosphere, and by transmission through the stem of the thermometer, if it is exposed to the temperature of the atmosphere.

The actual temperature of evaporation may be limited by the capacity of a given weight of air, under given conditions of initial temperature and initial moisture content, to give up heat and to hold a definite quantity of saturated vapor within the space it occupies at the temperature it assumes as a result of the process. Or the resultant temperature may be limited by the rates of diffusion with which the latent heat may pass outward through the gas film at the surface of the liquid and the inward flow of heat through the film from the surrounding atmosphere. If the rate of diffusion of latent heat outward is greater than or equal to that required for maintaining the temperature of adiabatic equilibrium, then the theoretical temperature of Equation [1] would be reached, but no lower temperature. If, however, this rate of heat flow outward, i.e., the diffusion of the vapor through the film, is less than the normal rate of heat flow from the outside atmosphere to the surface, at the theoretical temperature, then the actual temperature of evaporation will rise until the two rates are balanced. This rise of temperature above the theoretical will be more marked with increased thickness of the gas film in contact with the liquid, as occurs at very low velocities, and becomes exceedingly small at high velocities where the thickness of the film is negligible. At ordinary room temperature the error in the wet-bulb depression in air moving only at ordinary convection velocities has been found to be from 14 to 18 per cent, while at transverse air velocities over the wet bulb of 1000 to 4000 ft. per min. the error is from 1.3 to 0.2 per cent.

The effect of increased wet-bulb temperature in decreasing the deviation from the theoretical temperature of adiabatic saturation is explained by radiation effects. The effect of radiant heat received by the wet surface is to raise the temperature of the surface above the true temperature of adiabatic saturation. At low wet-bulb temperatures this effect is appreciable. However, as the wet-bulb temperature is increased the change in total heat per degree is rapidly increased and the total heat transformation from sensible to latent heat at the evaporating surface becomes larger relatively to the heat received by radiation. Observations herein presented have shown, for instance, that at an air velocity of 1000 ft. per min., over the wet bulb, an observed wet-bulb temperature of 40 deg. fahr. is in error by 1.72 per cent of the observed wet-bulb depression, while at a wet-bulb temperature of 100 deg. fahr. the error is but 0.86 per cent of the observed depression.

The Verification of the Equation of Heat Balance

For the purpose of demonstrating experimentally that the true wet-bulb temperature is the temperature of adiabatic saturation and that this temperature remains constant throughout the process of saturation so long as the total heat of the mixture remains constant, an adiabatic saturator was constructed the diagrammatic section of which is shown in Fig. 1.

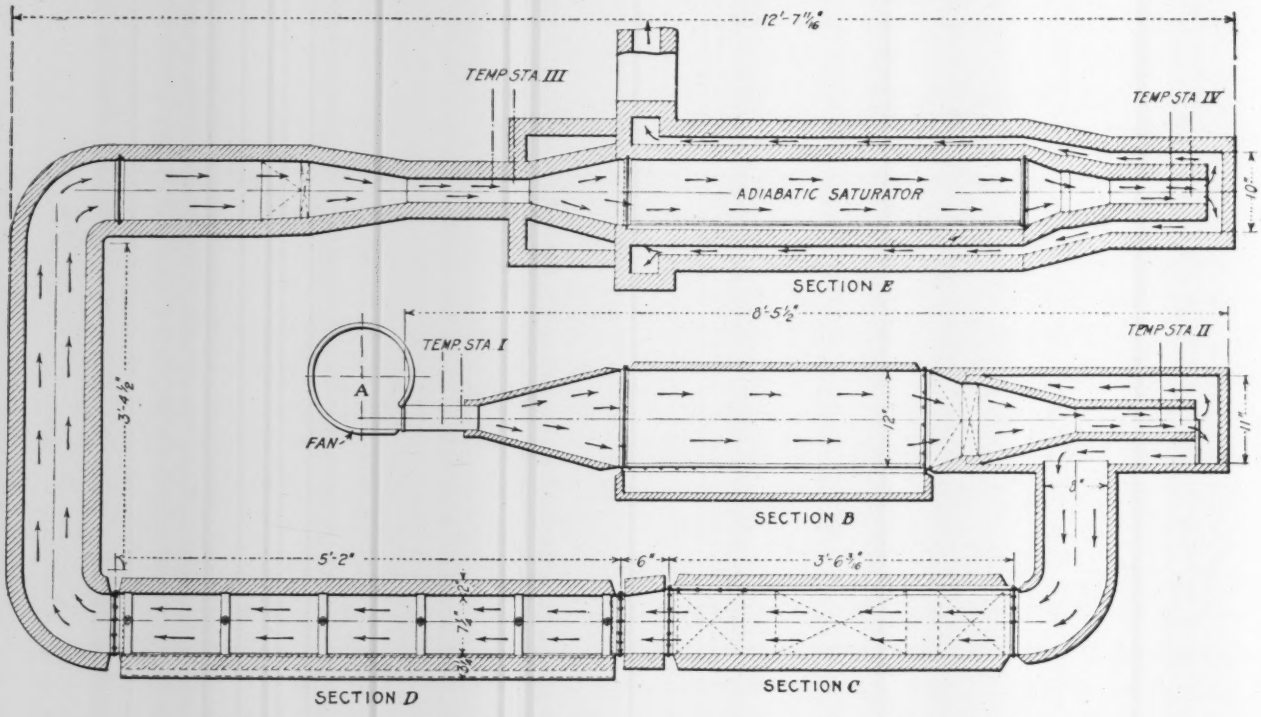

FIG. 1 DIAGRAMMATIC SECTION OF APPARATUS INCLUDING ADIABATIC SATURATOR

Driven by fan A the air passes through section B where it is saturated, thence through section C where it is heated to the desired temperature, thence through section D and finally to section E, the adiabatic saturator.

The wet- and dry-bulb temperature of the air entering the adiabatic saturator are measured at temperature station III. The air then passes through the saturator where it evaporates moisture, to a point approaching saturation, by passing over wetted cloth strips wound over and under pipes lying parallel to the air flow. The cloth strips and inner walls of the saturator are kept wet by a small gear pump recirculating water from the bottom of the saturator to the headers and distribution pipes at the top, from which it flows down over the cloths. Water evaporated is replaced by water supplied from an airtight tank on top of the saturator, a small amount of water entering the saturator whenever the level of the liquid in the bottom is low enough to permit an air bubble to pass through the connecting pipe into the tank.

Upon leaving the adiabatic saturator, the air is usually within one or two degrees of saturation, that is, the entering dry-bulb temperature has been lowered nearly to the wet-bulb temperature, due to the conversion of sensible heat to latent heat. At tempera-

ture station IV the wet- and dry-bulb temperatures are again observed. From here the air is returned over the entire inner casing of the saturator and is finally discharged.

The diameter of each duct where temperature observations were made is 3 in. Like air velocities were produced over each set of thermometers.

Very careful methods were used for temperature control and to prevent change of total heat in the adiabatic saturator.

In the experimental methods employed a number of corrections were made for the heat conveyed to the liquid by the pump, and for change in wet-bulb temperature due to change in total air pressure between the inlet and outlet of the saturator.

Table 1 shows the results of adiabatic saturation as accomplished

TABLE 1 SHOWING CONSTANCY OF WET-BULB TEMPERATURE THROUGHOUT PROCESS OF ADIABATIC SATURATION

Velocity of air over thermometers = 2000 ft. per min.

(1) t' Wet-bulb temperature entering adiabatic saturator	(2) $t-t'$ Wet-bulb depression entering adiabatic saturator	(3) $t_2-t'_2$ Wet-bulb depression leaving adiabatic saturator	(4) t'_2 Wet-bulb temperature leaving adiabatic saturator	(5) $t'-t'_2$	(6) Error in per cent of entering depression, $\frac{t'-t'_2}{t-t'}$
47.0	9.8	0.68	46.97	0.03	0.30
53.5	11.7	0.17	53.45	0.05	0.43
53.0	11.5	..	52.97	0.03	0.26
54.7	13.5	..	53.99	0.08	0.59
54.8	21.3	1.69	54.66	0.14	0.66
55.1	19.4	..	54.99	0.11	0.57
61.5	20.8	..	61.45	0.05	0.24
64.0	10.6	..	63.86	0.14	0.71
69.25	23.3	0.34	69.09	0.16	0.69
69.90	23.1	1.08	69.78	0.12	0.52
75.30	19.7	0.38	75.23	0.07	0.35
75.30	20.0	..	75.23	0.07	0.35
79.70	34.4	1.12	79.49	0.21	0.61
78.40	41.4	4.75	78.25	0.15	0.36
80.00	22.0	..	79.97	0.03	0.14
82.50	24.0	..	82.44	0.06	0.25
82.70	25.5	..	82.65	0.05	0.20
84.30	44.7	3.49	83.14	0.16	0.36
94.85	50.0	3.52	94.58	0.27	0.53

with the equipment. The temperature t' is the wet-bulb temperature of the entering unsaturated air. The difference between the wet and dry-bulb temperature of the entering air is given in column 2. The temperature t'_2 is the wet-bulb temperature of the air leaving the adiabatic saturator and is, as predicted, essentially identical with the wet-bulb temperature of the entering air, while the dry-bulb temperature of the entering air has dropped almost to the wet-bulb, as shown in column 3, wherever the dry-bulb temperature of the leaving air was observed.

There is a slight difference between the observed t' (entering wet bulb) and t'_2 (leaving wet bulb). It will be noted that t' is, in all cases, slightly higher than t'_2. This is due to the fact that the thermometer from which the values for t' (the entering wet bulb) were observed was exposed to radiation and conduction from the surrounding surfaces, which were at the temperature t (of the entering dry bulb). The thermometer, from which the values of t'_2 (the leaving wet bulb) were observed, was so protected from radiation and conduction, that the true wet-bulb temperature was registered. The difference between t' and t'_2 is shown in column 5; and the mean of these observed differences at a given wet-bulb temperature is taken to be the deviation of the wet bulb, due to radiation and conduction, from the true wet bulb as represented by the values of t'_2. This deviation is expressed, in Column 6, as per cent of the wet-bulb depression of the entering air. In the light of these observed percentages of deviation from the true wet-bulb temperature and from a mathematical extrapolation of the deviations observed at lower velocities, the absolute errors in wet-bulb depression were established at the various temperatures and at an air velocity over the wet bulb of 2000 ft. per min.

Fig. 2 shows graphically the conclusions reached and is consistent with the succeeding data showing the errors at various velocities. It will be noted that the errors from Table 1 plotted in Fig. 2 for the most part lie below the curve drawn to represent the errors over the complete range of temperature. The curve was drawn through points determined by the final equation which was found to be most consistent with all of the experimental determinations. It is likely that a very small quantity of heat was admitted to the adiabatic saturator from the outside sources and the effect of this would be to reduce the observed error, particularly at the lower temperatures.

QUANTITATIVE DETERMINATION OF THE VARIATION OF WET-BULB ERROR WITH VELOCITY AND TEMPERATURE

To accomplish adiabatic saturation and thereby produce the true wet-bulb temperature for a given heat condition is more difficult than to show the degree of variation in wet-bulb temperature with variation in velocity and temperature, if this variation is referred to a fixed temperature at a fixed high velocity instead of to the theoretical temperature. For instance, it is not difficult to observe the difference in temperature between two wet-bulb thermometers subjected to the same heat conditions but one being subjected to an air velocity of 15 ft. per min. over the bulb while the velocity over the other bulb is 2000 ft. per min. Neither is it difficult to compare two sets of such observations taken at different temperatures and thus show the variation of the difference with variation in the wet-bulb temperature. This was the

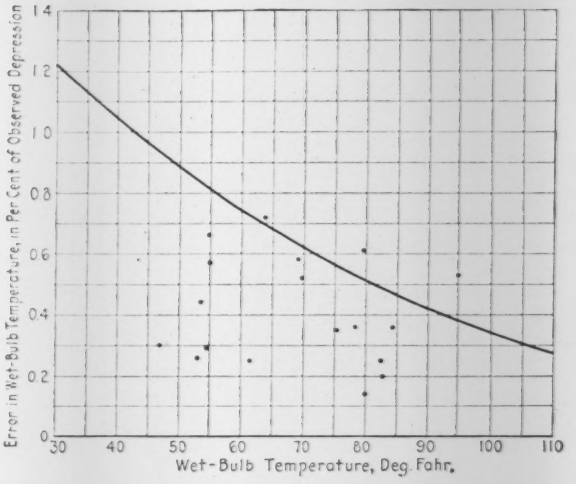

FIG. 2 WET-BULB ERROR IN PER CENT OF OBSERVED DEPRESSION
(Transverse air velocity over wet bulb = 2000 ft. per min.)

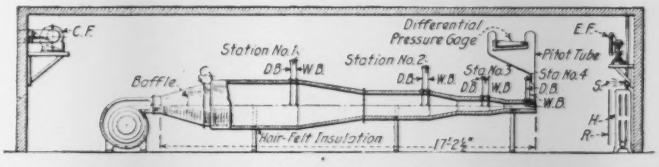

FIG. 3 APPARATUS FOR DETERMINATION OF ERROR IN WET-BULB TEMPERATURE DUE TO VARIATION IN TRANSVERSE VELOCITY OVER THE WET-BULB THERMOMETER

(D.B., dry-bulb thermometer; W.B., wet-bulb thermometer; C., two cloth distributors giving uniform velocity over entire area of duct; C.F., small conoidal fan to deliver outside air, controlled by hand damper; E.F., electric fan to produce uniform room-air circulation; H., heater, hand controlled; R., radiation shield; S., hand-controlled steam spray for humidity control.)

object of a second series of experiments which were conducted at Case School of Applied Science.

The apparatus used in these experiments is illustrated in Fig. 3. Briefly it consisted of a fan supplying air to a metal pipe which was about 17 ft. in length and which was divided into four velocity stages. Each successive stage was so reduced in area that the velocity of air through that stage was four times greater than the velocity through the preceding stage. The outlet of the pipe was 3 in. in diameter. As an example, approximately 100 cu. ft. of air per min. is supplied to the duct to produce an outlet velocity of 2000 ft. per min. Under this condition the velocity at the successive stages is as follows: Stage 1 = 31.25 ft. per min.; Stage 2 = 125 ft. per min.; Stage 3 = 500 ft. per min., Stage 4 = 2000 ft. per min. Wet- and dry-bulb thermometers were placed in suitable positions at each stage and simultaneous observations of the wet-bulb depression were made between any two stages under compression. With the proper corrections for the slight temperature change due to pressure change between the stages, a comparison of the wet-bulb depression at any stage with that of the final stage gives the difference in wet-bulb error due to the known difference in velocity. Similar sets of observations taken at different wet-bulb temperatures permit a comparison of the difference in error due to the variation in wet-bulb temperature.

Eight complete sets of observations were taken in this series of experiments.

An additional third series of experiments was performed to determine the difference in the wet-bulb temperature registered by a wet-bulb thermometer subjected only to the air velocity produced by natural convection and that of a sling psychrometer subjected to the same air conditions but whirled at an approximate bulb velocity of 1350 ft. per min. The observations of the stationary wet-bulb temperature were made with the bulb shielded on four sides by a muslin screen. This permitted free diffusion of the atmosphere about the bulb and allowed vertical convection, but protected the bulb from lateral drafts.

As a result of the three series of experiments described we have data covering, first, the total error in wet-bulb temperature at an air velocity of 2000 ft. per min. and over a considerable temperature range as shown in Fig. 2. Data showing the *difference* in error at a velocity of 2000 ft. per min. and velocities as low as 10 ft. per min. at four different temperatures have also been obtained. Finally the difference in error between 2000 ft. per min. and zero transverse velocity at one temperature was tabulated. It now remained to assemble these data and derive an equation which would cover the entire useful range of velocity and temperature.

The observed errors were corrected to correspond to absolute errors and are plotted against velocity in Fig. 4.

In an appendix to the complete paper it is shown that the error

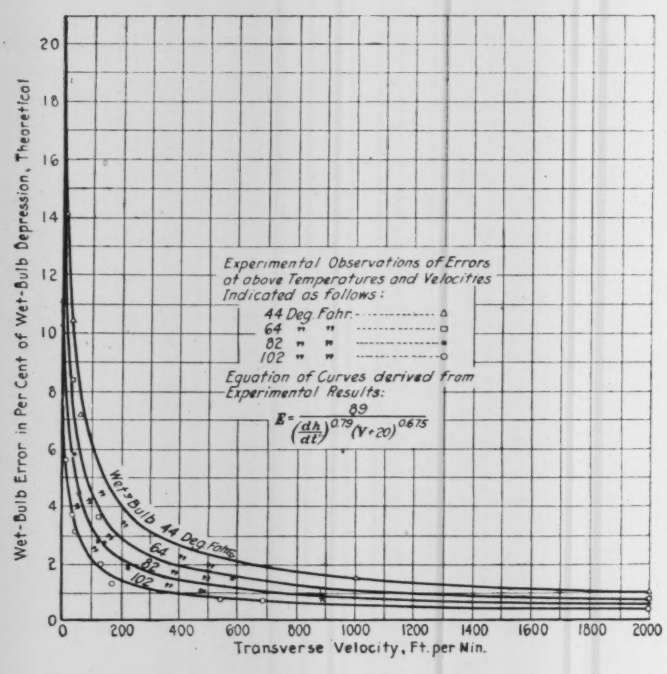
Wet-Bulb Error in Per Cent of Wet-Bulb Depression, Theoretical
Transverse Velocity, Ft. per Min.
Experimental Observations of Errors of above Temperatures and Velocities Indicated as follows:
44 Deg. Fahr.
64 " "
82 " "
102 " "
Equation of Curves derived from Experimental Results:
$E = \frac{89}{\left(\frac{dh}{dt'}\right)^{0.79}(V+20)^{0.675}}$
Wet-Bulb 44 Deg. Fahr.
64 "
82 "
102 "

FIG. 4 ERROR IN WET-BULB DEPRESSION AT TRANSVERSE AIR VELOCITIES FROM 0 TO 2000 FT. PER MIN., AND AT TEMPERATURES OF 44, 64, 82, AND 102 DEG. FAHR.

in the wet-bulb temperature must vary as an inverse function of the total velocity of the air over the bulb.

$$E = \frac{C}{(V + V_0)^{\alpha}} \qquad [6]$$

where

E = absolute error in per cent of the theoretical wet-bulb depression
C = a constant
V = transverse velocity of the air over the wet bulb
V_0 = velocity of natural convection over the wet bulb
α = a constant exponent.

This may be written

$$\log E = \log C - \alpha \log (V + V_0)$$

The convection velocity was taken to be $V_0 = 20$, the value having been determined by solving for V_0 from observations and selected as the value which best satisfied the equation throughout the velocity range.

In Fig. 5 the logs of the values of E taken from the curves in Fig. 4 and the logs of the observed values of E as recorded in Fig. 4 are plotted against the logs of corresponding total velocities $(V + 20)$. The result is a set of four parallel straight lines, each having the equation

$$\log E = \log C_t - 0.675 \log (V + 20)$$

Thus the exponent of velocity is found to be

$$\alpha = 0.675$$

It is also shown in an appendix that the error E varies as an inverse function of the change in total heat per degree change in the evaporating temperature of the mixture of gas and vapor.

$$E = \frac{C}{\left[\frac{dh}{dt'}\right]^{\beta}} \qquad [7]$$

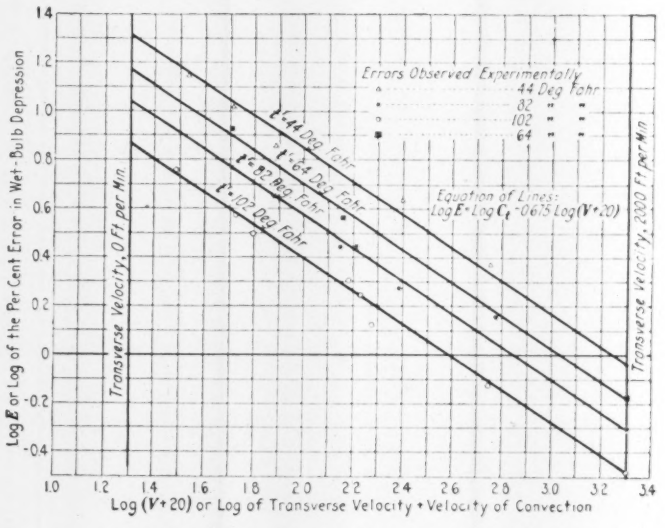
Log E or Log of the Per Cent Error in Wet-Bulb Depression
Log (V+20) or Log of Transverse Velocity + Velocity of Convection
Errors Observed Experimentally
44 Deg. Fahr.
82 " "
102 " "
64 " "
Equation of Lines:
Log E = Log C_t - 0.675 Log (V+20)
t = 44 Deg. Fahr.
t = 64 Deg. Fahr.
t = 82 Deg. Fahr.
t = 102 Deg. fahr.
Transverse Velocity, 0 Ft. per Min.
Transverse Velocity, 2000 Ft. per Min.

FIG. 5 LOG OF PER CENT ERROR IN THE THEORETICAL WET-BULB DEPRESSION VS. LOG OF THE TRANSVERSE AIR VELOCITY PLUS THE VELOCITY OF CONVECTION

where C = a constant

$\frac{dh}{dt'}$ = change in total heat of mixture per degree change in wet-bulb temperature

or

$$\frac{E_{t1}}{E_{t2}} = \left[\frac{\frac{dh}{dt_2}}{\frac{dh}{dt_1}}\right]^{\beta}$$

which may be written

$$\log E_{t1} - \log E_{t2} = \beta\left(\log \frac{dh}{dt_2} - \log \frac{dh}{dt_1}\right)$$

But from Fig. 5 the differences in the logs of errors for any two temperatures is found to be the constant distance between two parallel lines. Thus from Fig. 5

$$\log E_{82} - \log E_{102} = \log C = 0.176$$

So the exponent of change in total heat is

$$\beta = \frac{0.176}{\log \frac{dh}{dt_{102}} - \log \frac{dh}{dt_{82}}} = 0.79$$

Equations [6] and [7] may now be combined, giving

$$E = \frac{C}{\left[\frac{dh}{dt'}\right]^{0.79}(V + 20)^{0.675}} \qquad [8]$$

Finally the constant C in Equation [8] may be determined by substituting known values of E and V. The equation then becomes

$$E = \frac{.89}{\left[\frac{dh}{dt'}\right]^{0.79}(V + 20)^{0.675}} \quad \ldots\ldots\ldots\ldots\ldots [9]$$

Using Equation [9], values of E have been computed over the entire useful range of temperatures and velocities. These values are recorded in Fig. 6, which gives the values for the error in the wet-bulb temperatures in percentages of the true, *theoretical* wet-bulb depression.

The wet-bulb error, as recorded for the various temperatures and velocities in Fig. 6, is computed for a barometric pressure of 30 in. The wet-bulb error varies with the barometric pressure since

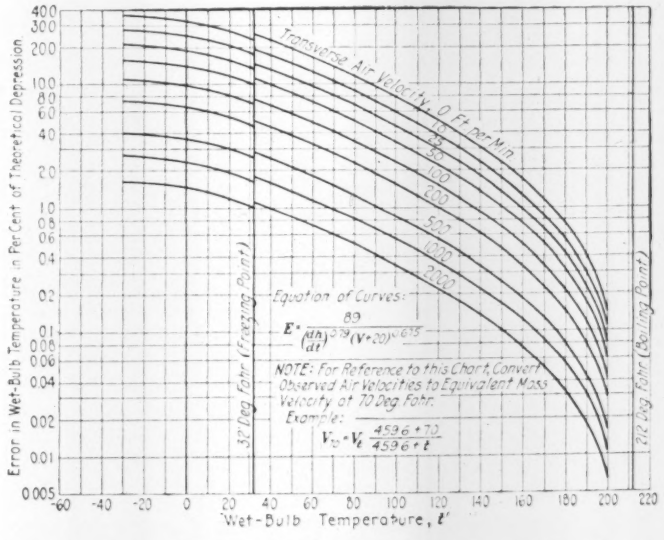

FIG. 6 ERROR IN WET-BULB TEMPERATURE EXPRESSED IN PER CENT OF THE THEORETICAL WET-BULB DEPRESSION AT WET-BULB TEMPERATURES FROM —30 TO 200 DEG. FAHR. AND AT TRANSVERSE AIR VELOCITIES OVER THE WET BULB RANGING FROM 0 TO 2000 FT. PER MIN.

the factor dh/dt contained in Equation [9] varies with the barometric pressure. Thus, as shown in Table 2, dh/dt' for a wet-

TABLE 2 dh/dt' CHANGE IN TOTAL HEAT IN B.T.U. PER POUND OF AIR PER DEGREE CHANGE IN WET-BULB TEMPERATURE

	Barometric pressure	
Deg. t' fahr.	30 in. Hg	25 in. Hg
(Over ice)		
−20	0.257	0.261
−10	0.271	0.278
0	0.291	0.300
+10	0.322	0.335
20	0.368	0.390
30	0.434	0.471
(Over water)		
30	0.391	0.426
40	0.455	0.501
50	0.543	0.604
60	0.660	0.743
70	0.814	0.932
80	1.02	1.20
90	1.30	1.55
100	1.68	2.03
110	2.18	2.66
120	2.83	3.50

bulb temperature of 60 deg. fahr. observed at a barometric pressure of 30 in. is 0.660, while dh/dt' for 60 deg. fahr. at 25 in. pressure is 0.743.

CONCLUSION

Perhaps the most important deduction to be drawn from this investigation is that under most practical conditions the temperature of evaporation of a free water surface approximates the theoretical temperature of adiabatic saturation, as very simply expressed in the fundamental equation of heat balance between sensible-heat and latent-heat interchange. (Equation [1].)

The variations observed were insignificant from an engineering standpoint—certainly at velocities above 200 ft. per min. In still air or at inappreciable velocities it is necessary to make an allowance and the magnitude of this allowance can now be fairly estimated.

It also follows from this study that the determination of relative rates of diffusion in the film of the vapor and of the gas can, for practical purposes, be entirely ignored and the relationship simplified. In other words, for practical purposes the engineer may treat problems of evaporation from a liquid to a gas, whether the heat be supplied from the liquid or from the gas, purely as a problem of conversion from sensible to latent heat. The assumption can always be made, as this study indicates, that the surface film is both approximately at the temperature of the liquid and at the moisture content corresponding to saturation at the liquid temperature.

It is because of this state of the film in contact with the liquid that the heat removed by evaporation must parallel in its amount the heat absorbed from the air by convection. The same effect holds where the liquid is heated, except that the amount of heat removed from the liquid directly by convection as sensible heat is in direct proportion to the amount of latent heat removed simultaneously from the film. It is also for this reason that the rate of evaporation is substantially proportional to the difference of vapor pressure between the liquid and the gas. The rate of evaporation is not caused by the fact that there are, theoretically, two different vapor pressures, one in the gas and one at the surface of the liquid, but by the fact that the density of vapor in the film is greater than the density of vapor in the surrounding air. That is to say, the weight of vapor per pound of air is greater in the film, and any mixture of the outside air with the film, as caused by velocity, whether of forced or natural convection, tends to carry away an amount of moisture which is directly proportional to the difference of moisture content between the films and the moving air. In other words, the evaporation of moisture from the liquid into the gas takes place exactly as heat transfer to air from a dry surface.

It has been shown that the law of wet-bulb error, from causes outside of the assumptions in the equations of heat equilibrium, varies substantially in accordance with the laws of heat transfer; that is, the exponent of velocities is substantially the same in this case as in the case of heat transfer.

It has also been shown experimentally that the effect of radiation upon wet-bulb temperature is directly related to the total heat of the air, that is, to the sum of sensible and latent heat in the air. Further, it is shown that the equation determined by experiment for this relationship is substantially the same as the theoretical equation as determined by the assumption of radiation as the sole cause of wet-bulb deviation. In the first case it varies inversely as the 0.79 power of dh/dt', while theoretically it varies inversely as the 0.7 power of dh/dt'.

It should be noted from the theoretical equation as given in an appendix that the error should vary slightly with the moisture content. In other words, the percentage of error will vary slightly with the vapor pressure, as well as with the wet-bulb temperature, inasmuch as it is a direct function of $(C_{pa} + C_{ps}w)$. In absolutely dry air this term will become constant at a given temperature since there will be no w, while in saturated air w will correspond to moisture content of saturation at the wet-bulb temperature. However this variation with the variations in wet-bulb depression is slight.

From a standpoint of exact measurements in psychrometry, the foregoing experimental determinations and deductions therefrom are believed to be valuable, since they determine for the first time with fair precision the corrections to be applied to wet-bulb observations in order to rationalize them with the true temperature of adiabatic saturation as determined by the physical properties of water vapor and air. It is also possible by the data obtained to rationalize the wet-bulb observations of a stationary hygrometer. It may be said, however, that without unusual precautions the stationary hygrometer is an exceedingly unreliable instrument for even the most ordinary work, since the drafts and convection currents existing in a heated room are uncertain, and consequently the corrections to be applied are uncertain. This is particularly to be emphasized, since the errors on a stationary wet-bulb thermometer occur on the most sensitive portion of the correction curves, i.e., at very low velocities.

Discussion at Refrigeration Session of A.S.M.E. Annual Meeting

AT THE joint session of the American Society of Refrigerating Engineers and The American Society of Mechanical Engineers, held during the Annual Meeting of the latter society, December 1 to 4, 1924, with George A. Horne, President A.S.R.E. in the chair, three valuable papers were presented. These were: The Temperatures of Evaporation of Water into Air, by W. H. Carrier and Daniel C. Lindsay, Newark, N. J.; The Flow of Liquids, by W. H. McAdams,[1] Cambridge, Mass.; and Water-Cooling-System Efficiency, by Victor J. Azbe,[2] St. Louis, Mo. Mr. Azbe's paper was published in the Mid-November, 1924, issue of MECHANICAL ENGINEERING. The paper by Messrs. Carrier and Lindsay, which appears immediately above in abstract form, will be printed later in Transactions, as well as the one by Professor McAdams.

DISCUSSION OF PAPER ON WATER-COOLING-SYSTEM EFFICIENCY

B. R. T. Collins[3] wrote that he believed Mr. Azbe's paper to be a very important contribution to the literature on water-cooling systems. Mr. Azbe had brought out the point that a cooling system might cool to within 3 deg. of the wet-bulb temperature in summer and no closer than 15 deg. in cold weather, the amount of cooling being the same in both cases. Cooling within 3 deg. of the wet bulb might indeed be obtained between early spring and late fall, but this would depend on the exact atmospheric conditions which existed, and no general guarantee to cool within 3 deg. of the wet bulb should be made.

The statement that spray systems were often installed in a manner that did not permit of successful operation was due to the idea that spray nozzles could be installed with close spacing and low elevation above the water level or roof, and also could be operated at various pressures and still yield efficient results. As stated by the author, each case should be studied carefully and a system designed to suit the conditions as they existed in order to secure efficient results.

The author stated that in winter a spray system would not give as cold water as a tower. In this connection the following results from a power plant log sheet might be interesting.

AVERAGES OF ELEVEN HOURLY READINGS BETWEEN 7:00 A.M. AND 5:00 P.M.

Average temperature after spraying	34.5 deg. fahr.
Average temperature before spraying	42.2 deg. fahr.
Vacuum	29.46 in.
Barometer	30.35 in.
Absolute back pressure	0.89 in.
Average temperature of outside air	8 deg. fahr.

It was fair to say that this plant was located in Montreal, Canada, although similar results could be obtained wherever the air temperature averaged as low as given above. As stated by the author, ice forming on a spray system caused no harm, whereas considerable damage was likely to occur from ice formation on cooling towers.

In regard to the practical design of spray systems, there were two most important points to be considered: first, their proper position in reference to the prevailing wind direction, and secondly, the providing of air lanes at intervals so as to enable light breezes to penetrate to the center of the system.

B. H. Coffey[4] and Geo. A. Horne[5] wrote that they agreed with the author that Equation [4] was unsatisfactory in that it compared the performance of the cooling apparatus with the maximum possible range from even initial temperatures; a range that perhaps the tower was not designed to produce nor was wanted by the purchaser. For instance, a forced-draft tower designed to cool from 110 deg. to 90 deg. would be at 70 deg. wet-bulb only 50 per cent efficient by Eq. [4], when in reality by area of surface and air supply it might be 98 per cent efficient as compared with a correct theoretical ideal. While Equation [6] was better than Equation [4], it was still, in the writer's opinion, very much open to the same objection.

On page 801 the author said that the writers had abandoned the fundamental Equation [7]. In this he was mistaken. In the writers' papers, in the *A.S.R.E. Journal* of Nov., 1916, and Nov., 1920, this theory had been verified and applied.

In his criticism of the writers' use of the wet-bulb and dewpoint to evaluate the transmission coefficient θ, the author disagreed on the nature of E. Because it had mixed temperature and pressure components as shown in Equation [2] he thought it could not be treated as a straight pressure potential in evaluating the transmission coefficient. Of course the whole basis of the writers' theory, which the author appeared to accept, was contrary to this view. It was only necessary to obtain a known effective pressure potential, a known surface, from which a known quantity of heat was flowing uniformly in unit time, these requirements being met by the relation between wet-bulb and dewpoint. There were special advantages in using this method given in the writers' paper in the *A.S.R.E. Journal* of May, 1916, pp. 15 and 17.

The author's proposal to evaluate θ with a small cooling tower in a wind tunnel might be difficult but quite possible provided very uniform distribution were obtained and the mean potential accurately determined. Transposing Equation [7], $\theta = H/ES$, in which E must be the mean value throughout the air-surface contact. The value of E was given in Equation [2], and in the proposed cooling tower the values of T, e_T, t, and e_t were variable throughout the contact and must be averaged. It was a question how this could be done easily and accurately.

W. H. Carrier[1] wrote that the author had used an equation which he, Mr. Carrier, had developed and which had been given in a discussion of Mr. Horne's paper appearing in the *A.S.R.E. Journal* of May, 1916. The experiments from which the formula had been established dealt with heat transfer by evaporation only; possibly the data in this discussion had been misused to represent the total cooling. These data had been replotted and compared with data of Messrs. Coffey and Horne and had been calculated for the rate of heat transfer on surfaces corresponding to that used by Messrs. Coffey and Horne, employing the coefficients obtained on pipe heaters. This comparison appeared in the Theory of Atmospheric Evaporation, *Journal of Industrial and Engineering Chemistry*, vol. 13, No. 5, May, 1921. Both of these curves were for evaporation only. In cases involving initial water temperatures above the wet-bulb temperature of the air the temperature heat or sensible heat had also to be taken into consideration for effective cooling as was done by Messrs. Coffey and Horne, by converting the temperature heat into equivalents of difference of vapor pressure and adding this to the latent-heat transfer vapor-pressure differences.

In recent work done by Messrs. Himus and Hinchley in England and described in a paper entitled Effect of a Current of Air on the Rate of Evaporation of Water below the Boiling Point appearing in the *Chemistry and Industry Review* of August 22, 1924, a higher initial rate of evaporation and a lower rate of increase with velocity were given than that shown by the writer. It was his opinion that this change of slope was primarily due to failure to stir the water so that the surface temperature would be lower than the surface temperature indicated by the thermometer.

It was also possible that the coefficient of transfer did not increase in precisely a straight line with the velocity. If the velocity were sufficiently increased and the observations were entirely accurate the slope of the curve would probably be found to decrease with an increasing velocity.

The values which Messrs. Himus and Hinchley gave for their experiments converted to the same units as those used by the writer would give the equation as follows:

$$\frac{H}{215} = 0.031\left(1 + \frac{V \times 0.00508}{2.29}\right) \times 25.4\,(e' - e)$$

$$= 169\left(1 + \frac{V}{450}\right)(e' - e)$$

Mr. Carrier believed, however, that the conditions under which their tests were conducted were not the same. It was to be noted again that these equations did not give total cooling but only evaporation, as applied in the case of water at the wet-bulb temperature of the air, and which was receiving its heat of evaporation only from the air.

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[2] Consulting Engineer, St. Louis, Mo. Mem. A.S.M.E.
[3] Spray Engrg. Co., Boston, Mass. Mem. A.S.M.E.
[4] Ch. Engr., Cooling Tower Co., Inc., New York, N. Y. Mem. A.S.M.E.
[5] Mt. Carmel, Conn. Mem. A.S.M.E.

[1] President, Carrier Engineering Co., Newark, N. J. Mem. A.S.M.E.

Attention should be called to the fact that the rate of heat transfer depended upon the type of surface and manner of blowing the air over it. A flow of air parallel to a surface would give approximately one-half the heat transfer as air at the same velocity impinging on that surface or blown transversely across it as in pipe coils. The type of surface and the direction of the air velocity must therefore be taken into account, as well as the air velocity itself. The ranges of heat transfer would probably always lie between the values given by the writer and those determined by Messrs. Coffey and Horne.

Edwin Burhorn[1] submitted a written discussion in which he said that in his opinion it was impossible to devise a really serviceable formula that could be used to design a cooling system. Reliance should rather be placed on the accumulation of test data on plants in actual operation. A theory of cooling could be devised only on the assumption that the water was properly exposed to the prevailing air and that the air was properly moving over the exposed water, and this was a matter that was controlled by the detail design and construction of the system.

The author had stated as a conclusion that the real competition in cooling systems was between atmospheric towers and spray systems, and that it was hard to say which was the better. The writer disagreed with the author on this point as it was very easy to say which was the better, provided the workings of the two systems in actual service were known and provided the data under consideration were reliable and unbiased.

Mr. Burhorn submitted some figures taken from the logs of three of the large ice-manufacturing plants in New York City. The figures were the daily records as kept by the operating engineers and could be considered as reliable. Plant No. 1 used a spray system as a cooling medium; plant No. 2 an atmospheric cooling tower; and plant No. 3 salt river water from New York Harbor.

Plant No. 1. The readings at this plant covered a period from June 15, 1924, to Sept. 25, 1924; they were taken daily at 8 A.M., 12 noon and 4 P.M. The figures given below are the average in each case for these periods:

Temperature of water entering the spray system	88 deg. fahr.
Temperature of water leaving the spray system	80 deg. fahr.
Air temperature	73 deg. fahr.
Head pressure	193 lb.
Current consumed per ton of ice	70.6 kw-hr.
Quantity of ice produced per day	228 tons
Volume of water consumed per day for all purposes	28,650 cu. ft.

The highest temperature of water entering the spray system was recorded on Aug. 7 and was 102 deg., leaving at 92 deg. with a head pressure of 225 lb. The lowest temperature of water entering the spray system was recorded on Sept. 11, 8 a.m., and was 72 deg., leaving at 64 deg. with the outside air at 52 deg. and a head pressure of 155 lb.

Plant No. 2. The readings at this plant covered a period from April 25 to Sept. 29, 1923; they were taken daily at 12 o'clock noon. The figures given below represents averages:

Temperature of water entering the tower	78.8 deg. fahr.
Temperature of water leaving the tower	76.2 deg. fahr.
Head pressure	161.7 lb.
Current consumed per ton of ice	52.17 kw-hr.
Quantity of ice produced per day	182 tons

The highest temperature of water entering the cooling tower was 90 deg., leaving at 88 deg. with a head pressure of 200 lb. on Aug. 5. The lowest temperature was on August 24: 65 deg. entering and 61 deg. leaving, with a head pressure of 115 lb.

The following tests were made to show the effect of different atmospheric conditions, and attention was called to the difference between the temperature of the water leaving the tower and the temperature of the wet-bulb thermometer.

Time June 21	Water entering tower, deg. fahr.	Water leaving tower, deg. fahr.	Wet-bulb temp., deg. fahr.	Dry-bulb temp., deg. fahr.	Head pressure, lb.
3.15	74	71	70	75	140
3.25	74	71	70.5	75	
3.40	73	70	69	74	
3.50	73	70	69	74	
4.00	73	70	69	73	
July 12					
1.00	89	84	80	88	185
1.30	89	83.5	80	88	

Plant No. 3. The readings at this plant covered a period from Apr. 25 to Sept. 29, 1923; they were taken daily at 12 o'clock noon. The figures given below represent averages:

Temperature of water entering condenser	63 deg. fahr.
Temperature of water leaving condenser	82.4 deg. fahr.
Head pressure	186.7 lb.
Current consumed per ton of ice	58.2 kw-hr.
Quantity of ice produced per day	283.7 tons

The highest temperature of the river water was 64 deg., the lowest 40 deg. The highest temperature of the water on leaving the condensers was 84 deg., the lowest 48 deg.

These figures showed the superior efficiency of the plant with the atmospheric cooling tower. A comparison of the spray system with the atmospheric cooling tower would show all the advantages in favor of the cooling tower with a possible exception of the item of first cost. A spray system might be put in to circulate a certain quantity of water for less money than a cooling tower of the same capacity, just as a simple steam engine could be installed to develop the same power as a compound condensing system, but the designer had to consider the first cost only as a part of the problem. Furthermore, if a spray system was really installed properly, with a collecting basin and a louver system to prevent an excessive quantity of water from blowing away and a protective system for preventing the reheating due to the action of the sun, then the first cost of a spray system might be considerably greater than that of a properly designed atmospheric cooling tower.

It was also Mr. Burhorn's opinion that the only means required for determining in advance what results might be expected from water-cooling systems at different times of the year, was a knowledge of the wet-bulb temperatures at different times of the year, as any cooling system could be designed and erected that would cool the water to the temperature of the wet-bulb thermometer. This applied to spray systems equally well as to cooling towers, but with the spray system it would require multiple spraying. From a practical standpoint, however, the cost of cooling to the wet-bulb temperature would be excessive and not justified by the increased economy obtainable thereby.

Mr. Burhorn advocated the design of a cooling system for refrigerating work that would cool the water to within 5 deg. of the temperature of the wet-bulb thermometer under the worst atmospheric conditions such as high temperature and low wind movement, and in connection with steam condensing, to the same final temperature provided the entering water did not exceed 90 deg. fahr. Where the temperature of the entering water was 100 deg. or thereabouts, cooling to within 10 deg. of the wet-bulb temperature was practical.

He also advocated the design of the pumps, or circulating medium, in units so that the amount of water circulated could be varied to suit different atmospheric conditions. With a high wet-bulb temperature it would be advantageous to increase the quantity of water circulated so as to reduce the range of cooling, whereas with a low wet-bulb temperature the quantity of water might be reduced, giving entirely satisfactory cooling results but reducing the cost of pumping. Theoretically, a direct-acting pump with speed control should be the logical solution of the problem. Practically, however, the direct-connected centrifugal pump seemed to be most generally in use, and this type of pump could be obtained with reasonably high efficiency provided the operating conditions were carefully determined and the pump designed to suit. With this type of pumping outfit, however, the speed could not be changed and the unit system should be adopted.

In the oral discussion which followed, Prof. W. H. McAdams criticized Mr. Azbe's suggestion that by determining the rate of heat transfer and the average potential in a spray apparatus, and employing coefficients obtained for a cooling tower in a wind tunnel, the unknown square feet of surface in the spray chamber might be determined. Professor McAdams thought this procedure unjustified because the coefficient of heat transfer in a spray system would not necessarily be the same as in an atmospheric cooling tower. He suggested that the square feet of cooling surface S might be replaced by the product aV, where V was the total cubic feet of cooling tower volume and a the square feet of surface per cubic foot. In this way where it was impossible to measure the square feet of cooling surface per cubic foot, the terms θ and a could be lumped together and the resulting coefficient related to unit volume.

[1] Pres., Edwin Burhorn Co., New York, N. Y. Mem. A.S.M.E.

DISCUSSION OF PAPER ON THE FLOW OF LIQUIDS

The general purpose of Professor McAdams' paper was to summarize the results of work in this field and to show that when a fluid was flowing inside a pipe a certain group of factors had an important influence on fluid friction, velocity distribution, and heat transmission. The paper reviewed the two possible types of flow, viscous or turbulent, and for isothermal flow discussed the mechanisms of the two types of motion, data being given to verify the mental pictures of the mechanism involved. It was shown that the dimensionless ratio Dus/z, where D was the inside diameter of a pipe, u the average velocity per second, s the specific gravity, and z the viscosity in centipoises, had a controlling influence upon the numerical value of the friction factor, the equivalent frictional length of an elbow, the ratio of average to axial velocity and upon a fourth dimensionless ratio involving the coefficient of heat transmission between the wall of the pipe and the liquid flowing inside the pipe. In addition auxiliary data were given as to the effect of temperature and concentration upon both viscosity and specific gravity, and of specific heat, specific gravity, and average molecular weight upon the coefficient of thermal conductivity. So far as it was possible, such data were given for fluids of interest to refrigerating engineers.

Harry Harrison[1] in a written discussion pointed out that very little would have to be done to make the paper an ideal technical audit of the subject, ready for use in planning experimental work.

G. T. Voorhees[1] inquired whether any actual experimentation had been carried out on the heat transfer with ammonia in pipes.

Charles Fromm[2] asked whether the influence of roughness of the walls had been given consideration in the paper with special reference to results obtained by Mr. Fromm and Professor Hupf in Germany.

In his reply, Professor McAdams pointed out that the paper was limited to liquids flowing inside pipes, and for that reason condensing ammonia would not ordinarily fall within the scope of the paper. However, when working with other vapors than ammonia, such as steam, benzol, carbon tetrachloride, etc. he had found that the thermal conductivity in the liquid state of the particular fluid being condensed and the viscosity of the condensate had important effects upon the quantitative results. In replying to Mr. Fromm, Professor McAdams referred to curves in his paper for the effect of roughness in turbulent motion. In viscous motion not so many data were available regarding the effects of roughness, but as far as he had been able to determine, the effect of roughness disappeared for viscous motion, or was at least far less important than for turbulent motion.

Simplified Control Methods in Manufacturing

Points Brought Out in the Discussion of R. E. Flanders'[2] Paper Dealing with the Design, Manufacture, and Production Control of a Standard Machine

THIS paper, which was presented at the recent Annual Meeting of the A.S.M.E. and appeared in the December, 1924, issue of MECHANICAL ENGINEERING, described the methods by which difficulties in manufacture and production control were avoided by the Jones & Lamson Machine Co.

The author states that the progress toward efficiency in direct labor cost had reached a point at which the company felt that further efforts in that direction would be unprofitable, and that it transferred its attention to other elements of cost and particularly to the largest of them—the manufacturing overhead.

As an examination of the various details did not indicate that they could be successfully improved by individual treatment, a major operation was performed which consisted in rearranging all the elements of the business so that difficulties were *avoided* rather than *overcome*. These radical changes are described in the paper. They consist briefly in segregating the manufacture of different lines, in redesigning the product, in rearranging departments by product rather than by process, and in reducing handling and clerical work.

Robert P. A. Taylor,[3] in the discussion which followed, said that a cardinal principle of design was economical manufacture. The author had designed and built up his scheme of manufacture and control at the same time that the product was designed. This scheme of control was based entirely upon: (*a*) a standard product; (*b*) the assurance of a wide market over a considerable period of years; and (*c*) the assurance of a constant and fairly steady demand.

If these conditions could be met, the whole plan became inoperative.

The problem of changing models should not involve any especial difficulties, but the likelihood of change of design was an important consideration if the type of management described was to be used.

Cost accounting served not only as a basis for determining selling price; it should also serve as another means of analyzing the product to locate excessive costs, either in material, design, or manufacture.

There was no apparent reason why the following features could not be included in the plan of management outlined by the author:

1 Bonus plan of wage payment
2 Time study (made necessary by 1)
3 Maintenance of record of performance
4 Maintenance of cost records.

These should be accepted only on a pay-as-you-go basis and they would much more than pay for themselves if properly handled.

The author was to be congratulated on conceiving and carrying into effect the type of management described. The machine-tool industry as a whole would do well to follow his example, where conditions and designs permitted.

Ralph G. Wells[3] said that the paper illustrated the value of simplification of control methods, and was indicative of the present trend toward less elaborate practice. Engineers had been using simplification of product and operation processes, but many had failed to apply this same principle to the control systems installed. Control methods were frequently too elaborate. There was a need for simplification of systems and a reduction of administrative overhead.

Mr. Flanders' remark that in seeking ways to reduce expenses and unit costs, the larger possibilities for saving might be found in manufacturing and administrative overhead, was worthy of emphasis. The increase in these items during recent years had been out of proportion to the savings effected. In spite of the improvements in management methods, the amount of burden which must be added to costs in many plants was not offset by a corresponding reduction in other items. It was encouraging to have this point emphasized and to have such an excellent illustration of what could be done. Instead of becoming disgusted with all control methods, this firm had had the vision and courage to work out from under too elaborate a system in a most effective manner.

In connection with the method of cost keeping, the question might be raised as to whether or not the present method gave sufficiently detailed information for comparing and analyzing costs in a search for further reductions. Not infrequently, under such methods as were described, it was possible for waste and idleness to creep in without its being detected as promptly as if detailed costs were kept and compared with predetermined standards. Perhaps the

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[2] Manager, Jones & Lamson Machine Co., Springfield, Vt. Mem. A.S.M.E.
[3] Crompton & Knowles Loom Works, Worcester, Mass.

[1] Refrig. Engr, New York. Mem. A.S.M.E.
[2] Newark, N. J.
[3] Research Service for Manufacturers, Boston, Mass.

standard of material and of working time gave a sufficient gage to check up waste of time or material if it occurred.

J. O. Keller[1] pointed out that the system of management described by the author conformed in principle to the known fundamentals of scientific management. The company knew exactly what it was trying to accomplish, and approached its problems in the mental attitude essential to scientific management. This attitude realized that experimentation and research were essential to success, not only with regard to materials and equipment but also to the human side of industry, which up to that time had been neglected. This mental attitude further realized that no matter how perfect present methods and devices might be, they would need improvement sometime in the future. This attitude was represented in the management of the Jones & Lamson Machine Company, as reported by the author.

Walter M. Kidder[2] said that the case of the Jones & Lamson Machine Company was of unusual interest. It was a typical case, in the course that eventuated through the stages of perfecting, along modern lines of design and general organization, raising operative efficiency, and finally the development of over-systemized routine. A second phase of especial interest lay in the ultimate reaction following a realization that "system" had become top-heavy.

Because the solution adopted as a result of that reaction was attractively simple, and had worked out satisfactorily, there was a strong possibility that similar methods might be attempted by others who were seeking relief from excessive overhead or insufficiency of profits. The warning must be given that the methods described would not work profitably in all cases; they surely would fail to give the hoped-for favorable results except under conditions to which they were fully adapted.

The excellence of the principles of design, of shop arrangement, and of conferring both authority and responsibility upon able foremen, as described by the author, was beyond question. So also was the objective of seeking to avoid difficulties rather than having to overcome them.

That the company had been able to accomplish this latter purpose in such large measure might be due in part to:

(*a*) Ample floor space
(*b*) Adequate plant facilities
(*c*) Able foremanship
(*d*) Workmen of native intelligence, and above the average in disposition toward team work.

Analysis of the description given by Mr. Flanders suggested the following friendly critical comments:

The problem in organization, after the point of accumulating essential data for establishing standards of performance under known conditions had been reached, was to formulate methods adequate to control without yielding to the temptation of excessive elaboration.

Few executives were so well informed in the field of methods for control and for enhancing profits by analytic methods that they could formulate methods without falling into the errors of either too much, too little, or the wrong kind of routine relating to control of production and of costs.

The Jones & Lamson Machine Company had been fortunate in having fundamental conditions of comparatively simple product, relatively small volume, and exceptional quality of personnel, and had therefore shown a certain success. But it might be quite possible and, in fact, seemed probable, that their profits could be further enhanced by conservative application of means which, at small cost, would add to both amount and certainty of net profits.

Apparently no classified records of spoilage were kept. Dealing with such occurrences on the instant had certain advantages, but even more effective in rooting out and permanently dealing with causes were adequate records which enabled analysis and the determination of both causes and personal responsibility.

Abolishing cost records of parts and disregarding their fluctuations seemed to constitute an omission to utilize a vital means for reducing cost and for consistently holding it to the lowest practicable level as to every part. Present knowledge of cost appeared to be limited to that required to fix selling prices. Unit reductions could not possibly be controlled effectively merely through knowing total machine costs. This opportunity for enhancing profits by direct action was apparently neglected.

Shop organization by product involved the employment of more machinery and more floor space than shop organization by process, assuming equally effective control of movement of product in both cases. Hence, greater capital investment was required in the first instance, and the idle hours of machinery would be greater. To some extent this would offset the saving in clerical labor achieved through substituting visual control of production in place of control through records.

Payment of producers on a straight wage basis failed to furnish incentive to high individual output and quality of workmanship. Both quality and quantity therefore depended, first upon the disposition and skill of workmen, and, secondly upon pressure exerted by the foremen. The temptation to foremen to employ the discredited "driving" methods of the past was increased.

Visual control of production with a sufficiently frequent check by actual count seemed ideal, but if product was varied and complex rather than simple, and in charge of average foremen, almost certain failure was invited. The method would work in conditions duplicating those of this Vermont shop, but might not under conditions which were materially different.

Dependence upon the uncontrolled, uncoördinated judgment and independent action of individual foremen created a condition saturated with risk. That it did not do so with the Jones & Lamson Company was a tribute to their foremen, and to their harmony of purpose and effort with each other and with the management.

In conclusion, it might be observed that this case of the Jones & Lamson Machine Company was a perfect example of success, but any one who was familiar with the contrast between a representative Vermont machine shop and the majority of those situated elsewhere, particularly in cities, would understand why Jones & Lamson succeeded and why copyists of their simplified and emasculated routine were liable to fail.

Copyists would be prudent to content themselves with emulating the company's thoroughness in developing productive efficiency in the shop, in standardizing and simplifying the design of product, and in the splendid "straight-line" layout of the shop floor. In the rest of the practices described by Mr. Flanders there lay too great possibility of trouble for shops located outside of the state of Vermont with its superior labor and foremen.

Luther D. Burlingame[1] made the statement that at the works of the Brown & Sharpe Manufacturing Company certain lines of manufacturing were carried on in almost identically the same way as described in the paper. An illustration of quite a different product, where such a method was used successfully, was the manufacture of micrometer calipers. In the manufacture of milling machines, the plan of having individual units so designed as to be used in as many sizes and kinds as possible had also had consideration. Thus, the speed case used on seventeen sizes and kinds of machines was made in five sizes.

The extra cost resulting from moving the work to various departments for successive operations was largely avoided when all work was done on a single floor, regardless of the particular plan.

The question of the need of keeping detailed costs would be somewhat different in a new organization where carefully kept detailed costs were not always available.

Although the method of paying workmen would not appear to be a necessary feature of the plan, it was thought that paying as far as possible by piece or premium rates stimulated increased production and gave the fairest possible return to the workman, dependent on his efforts. In the matter of having certain lines of work done in separate departments, for example, screw-machine work, gear cutting, planer work, etc. both for machines in process and also for parts made for sale, much could be said for having these as organized departments rather than having such machines separated for each line of manufacture.

Henry P. Dutton[2] said that the author's description of the meth-

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[1] Industrial Supt. and Pat. Expert, Brown & Sharpe Mfg. Co., Providence, R. I. Mem. A.S.M.E.

[2] Professor of Factory Management, Northwestern University, Evanston, Ill.

ods used in the reduction of overhead expense, and the philosophy which he expressed, constituted a clear statement of a situation which had demanded attention for some time. Wherever possible it was certainly advisable to secure control rather by simplifying the situation so that decisions could be made by ordinary men unaided. Such a system should be effective not only in reducing clerical expense, but by making most effective use of the initiative and intelligence of the man in the ranks, a force we had been prone to neglect. Methods such as those described by Mr. Flanders seemed to offer one of the practicable remedies for the condition of monotony and lack of incentive in industry, of which so much was heard.

The shop layout outlined by the author was apparently almost ideal in its directness of flow. Perhaps too general an assumption was made as to the possibility of using the product layout, since in many plants such product departmentalization would be secured at the cost of considerable overequipment.

The impression created on G. E. Hagemann[1] by this paper was that a slight sacrifice had been made in the absolute control of manufacturing, but that as a result a much more satisfactory and profitable method of operation had been developed. This was only natural as the problem of manufacturing was not so much one of complete control over all operations as it was of getting the most economical returns from the investment after it was put into the business.

From Mr. Hagemann's experience along the lines of management in other companies, it would seem that the work of the author and his associates should be credited with other advantages in addition to those which he correctly and justly claimed in his paper. One of these advantages was the restoration of at least a part of the old element of personal contact between management and foreman, and foreman and workers, which scientific management in its first developments had naturally tended to lose.

E. P. Bullard, Jr.[2] said that overhead had a faculty for creeping in unexpectedly in many disguises. In this paper it appeared in the standard drawings with established tolerances, material specifications, jigs, tools, and fixtures for production of this kind, which implied planning, time study, cost and records, all of which called for overhead. Then of course the proper shop arrangement for a plan of this kind could be provided only when certain essentials, such as the methods and costs of manufacture, had been used in their correct relation to each other, as obtained from previous records of each and every operation.

Placing raw material in bins, available to the various departments, required control of a high order if no check was to be made of its outgo. The flow of material through a department, from the raw to the finished state, required an established sequence of operation so timed that all parts would come together at a predetermined time and place for assembly. The rate of flow through a department would depend upon the time required for the longest operation, and all other operations must conform thereto. Overhead might appear easily in the form of idle equipment, excessive floor space, and inefficient operation.

Reference was made to the fact that no stock-room records were kept. Apparently, the author presupposed that inventories of raw, in process, and finished parts remained constant. Thus he argued that the cost of completed machines was represented by total payroll, material purchases, and expenses for that division. These conditions, however, did not obtain. Therefore any costing of a period of varying manufacture would neither be reasonably accurate nor give comparable results. Inaccuracy would obtain in the separation of costs of the three types of machines made.

From an accounting standpoint it was necessary to begin with the values of finished machines, finished parts, raw materials, and work in process. These values must be determined from actual costs or from estimates.

It was the general custom to take a period of 12 months for actual closing of books and figuring of profits, and in order properly to determine the value of the inventory at the end of the period as compared with the beginning of the period, it would seem necessary actually to count and price each individual piece of finished parts and raw material, and to estimate the value of the work in process, all of which would be extremely difficult and expensive.

The scheme, as outlined, placed the burden upon the foreman. It was he who must determine the quantity to be produced, ascertainable only after an actual count of the number of pieces of any given machine in the store room, and of raw material in the stock room, and he also must oversee production. As it would be impossible for any one man to do all that, he must have assistants—and if assistants were necessary, it would certainly require but little additional time to compile an accurate record of the findings, which could be referred to at all times, and a perpetual inventory of items could be maintained without any additional cost.

It would seem, therefore, that the cost of obtaining any figures by which it would be possible to show the gain or loss of the year would be just as high in determining the estimated value as it would in determining the true value, with the further disadvantage that, while with the ordinary method we were constantly in touch with the situation, with the physical inventory at the end of the year nothing was known until it was all taken and computed.

The real object of the author was an effort to control the overhead. This was certainly very desirable, for there was no doubt whatever that overhead was a more fixed item in a plant than direct labor. Mr. Bullard believed, however, that the author's plan would not eliminate overhead to the extent he assumed it would.

John H. Williams[1] found that the paper and the discussion had largely centered around the question of the extent of records and the extent of management control. A means of determining the desirable amount of paper work was to realize that the only possible purpose this work would serve in management was to augment the memory and to facilitate the coöperation between different persons who must exercise a controlling function. Any paper work that went beyond those two requirements was, and deserved to be called, red tape.

Author's Closure

In his closure to the discussion, the author, Mr. Flanders, emphasized the fact that the particular scheme described in the paper should not be regarded as a panacea for all kinds of manufacturing problems. It did not apply to cases where the product could not be controlled as to design, or where it was subject to the whims of fashion. Neither did it apply to businesses made up of a large number of separate items never assembled into one uniform mechanism. It did apply, however, to a large range of manufacture and particularly to the manufacture of machinery of ordinary size in all sorts and varieties. It was only on the particular work to which it did apply that he urged its adoption in any form.

Mr. Flanders also desired to remove any impression that the paper implied criticism of management engineering as it was known today. He distinctly wished to imply that the management engineer had provided control schemes for business which ought not to exist at all in their present form; the expert had often been asked to provide for the control of a business where the product ranged through from 50 to 500 sizes, varieties, kinds, and types, when there should have been but one, two, or three. The difficulty lay with the original management of the company itself.

In such a case the main effort of the company should not be expended in systemizing their business in its present form, but in fundamentally changing the business itself in the direction of specializing on a smaller number of items of output with a corresponding constructive effort on their sale. Such a policy generally followed would reduce the cost of manufacture, and help to reduce the retail cost to the public of a very wide range of useful and necessary articles. Of course, such standardized production did not always apply to objects of pure beauty as distinguished from objects of usefulness, nor was the policy proposed always consistent with the progress of change and invention; but he was strong in the belief that a very large area of the productive field was ripe for this simplification and standardization, and it was as a contribution to this particular area of industry that the paper had been presented.

It should also be especially observed that the needless complication of business had demanded an unusual mental capacity on the

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part of the management engineer, and an unusual and rather rare type of personality, of which Mr. Taylor, Mr. Gantt, and Mr. Gilbreth stood as shining examples. It was the rareness of this type that had held back the development of management. It was only by deliberate simplification of the problem that we of less outstanding genius could carry on the work which they had left undone.

Before giving detailed answers to the various criticisms and suggestions raised in the discussion of this paper, fairness required that a statement should be made of the exact present condition of the system of production control described in the paper. So far it had been applied to a very small scale of production. This was one of its most encouraging features. It had resulted in an overhead cost that was only about 25 per cent greater, measured in cents per hour, than the average overhead costs of a period when the company's output was three or four times its present volume. It was felt, therefore, that at least one of the desired results had been effectively obtained.

The program method of scheduling had been in effect on the work over a period of several months with the exception of one feature: they had not yet in this department definitely predetermined on what particular machine a given job should be done when several machines were available, but since they had carried out this practice in previous years they had no doubt but that in the future they would be able to preplan easily and simply the machines on which the work should be done.

Answering Mr. Taylor's questions, Mr. Flanders said that in preparing the routing schedule, the time in hours was arrived at by estimates based on former records of performance. Radical changes in design seldom required parts of a radically different character from those previously made, but where they did require some completely unfamiliar operation, a new time study would have to be made.

In the event that he would be considering a plant for making six models of milling machines and three models of grinders, he would be inclined first to see if it were not possible to bring a large number of units of the milling machines to a common design, and try to do the same thing on the grinders. If this was possible, he would make a grinding-machine department and a milling-machine department, each with practically their own complete equipment, and endeavor to run them on the basis described in the paper.

With regard to the yardstick with which to measure the foreman and the output, he would say that this yardstick was based in the case of the Jones & Lamson Company on time estimates derived from past experience. The important part about this whole thing was that this rate of production that had been attained in the past, whether 100 per cent or not, was very creditable as compared with the top-heavy overhead expenditures which accompanied it, and the company's reasons for not worrying very much as to whether they had gotten down to the last few fractions of a cent in time-study refinement were that the efforts were not worth while as compared with the very large reduction possible in the overhead. The real measure, after all, of the usefulness of the foreman and the workman under this scheme was his ability to stick to the schedule and thus promote the easy, orderly, and profitable progress of the work through the shop, irrespective of whether that progress in certain details was quite as fast as it ought to be. The schedule as a whole made it fast enough to be profitable.

Mr. Flanders did not see that there was any less responsibility devolving on the individual foreman, as indicated in Mr. Taylor's question, than there was in any other system of management which endeavored to plan things ahead of time; and so far as increases and promotions could be based on records, the good record in this system of management was that of the man or of the foreman who kept up the schedule and thus contributed to the orderly production of so many machines per week at a reasonable cost.

Mr. Taylor, and a number of others had been troubled about the comparatively rudimentary nature of the cost figures. Getting detailed cost figures on operations where such figures had been kept over long periods of years was a sterile, fruitless operation so far as making large savings in cost of manufacture was concerned, particularly when compared with the immensely larger savings to be made from attacking the overhead directly. Why worry about the cents when the dollars were melting away?

Above all, he would not hesitate about cutting out a function because it might sometime be needed, as Mr. Taylor suggested. He would cut it out on suspicion, and only put it back in later if he found he would not get along without it. This did not mean throwing the whole production mechanism out of the window. It meant retaining that which had proved to be essential, and discouraging the rest.

People were often deceived by their success in putting the time and effort of a high-grade man on some detail of cost accounting, and thereby making a definite saving in that area of investigation. That saving would only be maintained so long as the original high-grade and highly paid investigator was on the job. It was the inevitable tendency of such detailed investigations to degenerate into rust and rot as soon as the original high-grade man had turned his attention to something else. It did not do to get too enthusiastic about the savings made by the skilled man; it was better to see if they could be maintained over a period of years by the work of the ordinary every-day clerk on whom routine duties finally devolved.

Mr. Well's suggestions were interesting. It was probable that the Jones & Lamson Company could not have had as good results as they had had with their simplified control methods if they had not previously gone through a more elaborate system of planning and scheduling. This, said Mr. Flanders, might be a confession, but it was the truth.

As mentioned in connection with other criticism, the present method of cost keeping would not ordinarily give sufficient detailed information for comparing and analyzing costs in search for further reduction; the reason being simply that the rich field for further reductions lay not in these direct costs, but in the overhead. However, every time card, every material card, and every element of cost was recorded and saved, so that at any time, if detailed cost studies needed to be made, the material was all there. They were not, however, at the present time working it up as a matter of routine.

Mr. Kidder seemed to fear that the plan of production control suggested would require more floor space and machinery. In the case under consideration the result had been surprisingly opposite to this. Mr. Flanders had found that the laying out of a standard production program was a more or less academic job; fitting the whole production schedule together like a picture puzzle or working it out like a game of chess, had produced such an effective use of the machinery that each element of it could be used a very much larger percentage of the total working hours than had ever been the case previously. His company's standard schedule therefore called for a higher number of machines per week produced from their present equipment than they had ever been able to get in practice.

The only conditions under which this scheme called for added equipment was in the highly specialized tools like broaching machines, tooth-rounding machines, spline millers and other such cases in which one machine had previously been sufficient for the whole plant. The dividing of the plant up into different departments for different products would require that in general each department should have its own machines of these highly special types.

With regard to the quality of the foremen and workmen, it was certain that they were proud of both, but if he, Mr. Flanders, were manager of a plant under similar conditions in regions which were supposed to be less Elysian than his native soil, he would expect this scheme of production to make things as much easier with unpromising material as it did with that of a higher grade.

With regard to floor space occupied, it should be noted that the rapid flow of the work, made possible by the scientific production program, required much less floor space than under the old scheme. Had the plan been adopted five years ago, many tens of thousands of dollars would have been saved on now unneeded shop structures built when costs were at their highest.

Any method of wage payment was possible with this scheme, as stated in the paper.

There was no automatic means to prevent the foreman from falling behind. However, his dates were given him in plain black and white, and it was easier for the superintendent and the foreman himself to see that he was falling behind his schedule than

it was where the instructions did not stare him in the face. It was the cases where the foreman was failing that would mostly engage his attention, and that of the production superintendent. That was, in fact, the work for which they were hired; to look after the points of weakness and failure.

There were no stock-room records, and the company had been running very successfully without them. Classified records of spoilage were, as a matter of fact, being kept. Sometimes they looked after this item of cost and sometimes they do not, depending upon whether or not the company was passing through a period where it was serious.

Mr. Hagemann was right in laying stress on the restoration in part of the old element of personal contact between management and foreman, and foreman and workers. There was still another immensely important element in the scheme, and that was the personal contact between the worker and his work. The importance of having individual workmen acquainted with the history of a piece of raw materials to finished machine, and having it all under his eye, could not be overestimated from whatever angle of the problem of management it was viewed. A person of vision and literary ability could write a whole book on this one subject alone.

Mr. Flanders hoped at some future time to remedy the omission that Mr. Hagemann noted; namely, the actual savings in dollars and cents brought about. The best that he could do on that subject at the time the paper was written was the more or less vague comparison given in the fifth paragraph of the present closure. Since the time when the Jones & Lamson Company had begun scientific production control, they had never worked under such a low schedule of production as they had during the year or so past. For that reason direct comparisons were difficult.

Mr. Bullard's criticisms were interesting, but it was probably impossible to answer them to his satisfaction. Mr. Flanders could only say with regard to the storage of raw material, for instance, that the placing of the reserve of forgings and castings in the department which used them had not resulted in any terrible loss. No one concerned would now care to go back to the old clerical way of looking after this matter, which now appeared to look after itself so well.

Mr. Bullard's criticisms as to the varying rates of flow were not quite clear. They were perhaps based on the idea of having everything come together at a given assembly point at a given time. As a matter of fact, however, a careful reading of the paper would show that assembly was continuous, so the problem was not that of having every part done and complete at a given point at a given time, but of keeping a minimum supply of all parts continuously on hand. In doing this, of course, some lots had to be started many weeks before they were needed, while others could be started only a few days before reserve supply was expected to get low. Furthermore, in a part like the headstock spindle, which had some very long operations and some very short ones, it was perfectly advisable to do as his company had done and to overlap the long operations; that was to say, the rough turning of a lot of spindles could start shortly after the boring operation had started on them. It did not need to wait until all the spindles were bored out. A vast amount of telescoping of the longer operations had been involved in laying out the standard program. Mr. Flanders could only assure Mr. Bullard that his fears of large inventories, burdens on the foreman, and the necessity for clerical assistants were completely groundless. These were difficulties which had been cured by this scheme.

With regard to the monthly statements, they had a quite high degree of reliability simply because manufacturing and assembling operations were continuous rather than cyclic. Otherwise Mr. Bullard's criticisms would be justified. Finally, with regard to his fears, it was to be said that whatever a careful theoretical consideration of the issue might show, the actual practice had resulted in a reduction in overhead.

Mr. Flanders realized that this problem and solution had been presented in the paper as though it were a problem in statics which had been solved once for all, and would require no further changes or development. That, of course, was not true. In the days after the paper had been written and before it had been presented minor changes and adjustments had taken place. In the period since the presentation of the paper and the final editing of the discussion, still other adjustments had had to be made. These changes and adjustments were not accidental and occasional features, but a part of the business management; but they had not as yet appeared to effect the usefulness of the fundamental principles on which this scheme had been based.

If these changes in adjustments should ever become sufficient in volume or interesting enough in kind to warrant presentation, concluded Mr. Flanders, it might be wise for him to offer to the Society a second paper which would not be concerned with the statics of management, but rather with its dynamics.

The Coming Conflict in Foreign Trade

STEADILY advancing prosperity and growth of productive capacity within the United States are among the best indices of our competitive powers in international commerce. We hear much of mass production and of its vast powers in determining competitive ability, but we do not always realize the tremendous advantage which the United States actually has in this connection. Our manufacturers were valued at about $25,000,000,000 in 1914; their value in the recent census of 1923 was indicated at approximately $60,000,000,000—a most impressive increase, even after allowance is made for liberal price changes that have taken place during the decade.

In pig iron, for example, the gross tonnage produced by the United States in 1913 was 30,600,000, which was practically the same as the combined output of the United Kingdom and Germany, at 29,300,000 tons. By 1924 this predominance had been almost doubled; that is to say, the American output was 31,000,000 tons, whereas the combined British and German output was only 15,600,000 tons. A similar situation prevailed in steel ingots, in which the American production in 1913 was some 31,300,000 tons, against the British and German combined total of slightly in excess of 26,000,000 tons. By 1924, however, the American production had risen to 37,800,000 tons, whereas the production of our two European rivals was slightly under 17,000,000 tons.

On the side of coal production, likewise, we have more than maintained our prewar supremancy, having reached more than 573,000,000 tons in 1924, or considerably in excess of the combined output of the United Kingdom and Germany. Our consumption of the world's crude rubber production, to take another index of industrial expansion, has arisen from 43 per cent of the total world output in 1913 to 77 per cent of a much greater output in 1924. Similar figures might be cited in many lines to indicate the truly impressive predominance of industrial America, a mastery which is bound to determine ultimately the direction of the world's commerce.

Fundamentally, the issue between the American exporter and his rival would seem to be one strictly of whether quality or cut prices should prevail. As between the two there is to be no question as to the ultimate decision of the American merchant or manufacturer. A strict adherence to those high standards which have long given American wares their standing in overseas markets would seem to be the best and, in fact, the only foundation for a lasting edifice in our foreign trade. It is probable that this may mean a loss in certain lines and trade centers, but there is some comfort in noting that European price cutting seems to be decidedly on the wane for several strong reasons.

First of all, the high rates of interest now being required by all lenders of capital, whether native or American, to European enterprises will present an increasingly serious problem for the European manufacturer. Secondly, he faces the inevitable accumulation of heavy taxes, from which relief might not be available for years. Thirdly, there is every indication of a steady upward climb of wage rates which in Germany, for example, are still 25 per cent below prewar purchasing power. Fourthly, with recovering exchange rates, as a result of stabilized currencies, one of the monetary advantages enjoyed by our competitors after the war is being wiped out. (From concluding portion of an address made before the American Manufacturers' Export Association, New York, March 25, by Julius Klein, Director U. S. Bureau of Foreign and Domestic Commerce, and published in *The Iron Age*, April 2, 1925, p. 963.)

Principles of Metallurgy of Ferrous Metals for Mechanical Engineers

First of a Series of Articles Discussing the Underlying Physical and Chemical Processes Involved in the Metallurgy of Iron and Steel, and Dealing Particularly with the Physico-Chemical Properties of Iron Alloys

By LEON CAMMEN,[1] NEW YORK, N. Y.

A PIECE of steel in many respects resembles one who examines it. Like him it has properties which are determined by the materials of which it is composed, by the treatment it has received—its life history, by forces that act invisibly within it, and finally, by its environment. It will be the purpose of this series of articles to discuss briefly all of those influences which contribute to make a piece of steel what it is, to the satisfaction or dissatisfaction of its users.

Every commercial iron alloy is essentially the product of an alliance, mechanical or chemical, between the primary elements iron and carbon, affected as it always is by the presence of what may be called subsidiary or incidental constituents such as manganese, silicon, sulphur, phosphorus, oxygen, nitrogen, and hydrogen. Special iron alloys have also such elements present as nickel, chromium, copper, cobalt, tungsten, molybdenum, etc. singly or in combinations of two or more. Finally there are elements which first appear in and then disappear from the iron alloy at some stage or other of its manufacture, producing beneficial or harmful results by virtue of some reaction which they have been instrumental in accomplishing. Metals like titanium and, to a certain extent, vanadium and such so-called deoxidizers as boron, aluminum, and magnesium may materially affect the character of a steel without being actually present in the final product, through the fact of their having introduced or eliminated undesirable constituents or exercised a more or less permanent effect on the structure of the metal. What is not always realized is that a very large proportion of the carbon used in the manufacture of steel acts in exactly this way.

In the first place, therefore, the character of a steel, or in fact, of all iron alloys, is determined by the materials that go into its making. It is also affected by the way in which the steel is made. The method of melting and, in particular, the ability to control the various steps in the process, and hence the final product, is one of the factors the importance of which has not been fully realized. The whole difference between bessemer steel on the one hand and open-hearth steel on the other, depends on this very fact. The excellence of many grades of electric steel is likewise probably due to the ability to control the product more than to any other factor.

The amount of gases dissolved in the steel, which affects the soundness of the ingot, is also a factor which may or may not be controllable during its manufacture, with the result that the strength of the ultimate product may be favorably or unfavorably affected by the degree of controllability exercised and by the knowledge of the extent to which dissolved gases should be permitted to remain in the steel at the time of its teeming.

Finally, the handling of the molten steel, a subject about which very little indeed is to be found in books, affects the character of the metal to a far greater extent than is generally realized. When steel is teemed from a furnace into a huge ladle and the ladle is set aside for, say, twenty minutes to permit the metal to settle, something is done which is of truly vital importance in determining the character of the final product, yet one may look in vain through metallurgical literature to find strict justification for this apparent waste of time.

The temperature at which the metal is poured into an ingot mold, the rapidity with which the latter is stripped and the ingot transferred to the soaking pit, the design of the ingot mold, the use or failure to use hot tops, the shape of the ingot, are all important items in the process of manufacture that determine each in its own way the properties of the final product.

As a matter of fact, from the moment the molten steel reaches the walls of the mold there are a series of processes at work in shaping its quality and characteristic properties which do not cease until the final operation on the product. The rapidity of freezing and cooling of the steel, its ability to hold dissolved gases, the thermal and chemical processes which produce what is known as segregation of the non-metallic elements, the strains in the ingot, the development of planes of weakness induced by these processes, and the character of crystallization of the steel are but some of the factors which determine the properties of the material in the ingot. The ingot is not, however, the final product except in the case of castings, and in all other cases it is but a starting point for other operations.

These operations, which comprise various kinds of forging, rolling, drawing, pressing, and heat treating, introduce numerous other influences which modify favorably or unfavorably the characteristics already present in the ingot, and these in their turn may be followed by a new group of operations such as machining, stamping, grinding, etc. at times capable of still further modifying the properties of the metal.

And then there is heat treatment, which, like the fiery bath of the fairy tale, permits steel to purify itself of most of its sins of improper crystallization, and, one might say, to start life anew, with a clean slate, and build up a structure that may be tough or brittle, hard or soft, practically as desired.

When, therefore, we look at a piece of steel we can envisage it in a way as a distinct personality with a long past history. We know that the character of a man is affected by the race from which he sprang, in other words, by those physical and mental ingredients which went into his original make-up. It is also affected by the conditions under which the most impressionable periods of his life—childhood and youth—were passed, by the schooling he received, and by the environmental influences that were brought to bear upon him. The same is essentially true of steel. The metallurgist has to know all of those influences which affect the ultimate character of steel just as an expert diagnostician has to understand similar influences in the case of a man. It is not an easy task because of the very great complexity of the factors affecting and determining the characteristic properties of steel, only a part of which have been enumerated above. There are, however, certain basic underlying processes and physical and chemical laws which lie at the foundation of all the vital processes governing the making, shaping, and treating of the master material of the world—steel. In the present series of articles an effort will be made to discuss somewhat briefly, and, as far as possible, in non-technical language, these basic underlying physical and chemical processes rather than the actual manufacture of steel through all its maze of complexities.

I—Physico-Chemical Properties of Iron Alloys

IN DEALING with ferrous metals, or alloys of iron such as cast iron, steel, and wrought iron, the mechanical engineer is primarily interested in knowing whether and why a certain piece of metal is tough or brittle, strong or weak, capable or incapable of withstanding vibration and repeated shocks, and whether or not it can be improved by proper treatment. Essentially, it is not the problem of the *mechanical* engineer to produce the kind of steel or cast iron which would answer his purpose. This is primarily the business of the metallurgical engineer, but it is important that the mechanical engineer should understand clearly what makes a certain material suitable or unsuitable for his purposes

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and what fundamental properties a material should possess to be suitable for the use to which he proposes to apply it. This is highly desirable because it will help him in preparing specifications for the material that he will use or to act intelligently in selecting the proper material for his purposes. Assume, for example, that a mechanical engineer is designing a boiler for a pressure of 600 lb. and a superheat of 600 deg. fahr. Here ultimately the material of the boiler is subjected to two influences: the mechanical influence of the pressure, which is comparatively easy to calculate by employing certain formulas; and the influence of the temperature of the steam, which may greatly modify the ability of the metal to withstand the mechanical stresses. Now, if an engineer were entirely ignorant of the fact that at temperatures in excess of 1000 deg. fahr. pronounced weakening occurs in ordinary steel, he might specify a material that would merely withstand certain mechanical stresses without calling the attention of the metallurgical engineer to the fact that unusually high temperatures were to be dealt with, and this would unquestionably result in the failure of the steel recommended. This is a rather crude example, but it will serve to show how important it is for the mechanical engineer to have a clear conception of the various influences affecting metals in order to be capable of dealing intelligently with the problem of selection of materials for his special purposes.

All ferrous materials (which term includes cast iron, malleable iron, white iron, carbon and alloy steels, and wrought iron) are essentially combinations of the element iron (Fe) and the element carbon (C). All commercial ferrous materials contain small or large additions of other substances, some of which are merely impurities derived from the ores, fuels, or fluxes and cannot be entirely removed in the process used for commercial manufacture. Of these the most important are sulphur and phosphorus. Other elements may either be inherited by the metal from its ores or be deliberately introduced into it during the process of manufacture for the purpose of counteracting the harmful properties of impurities or conferring on the metal certain desirable properties. Among these may be mentioned manganese, silicon, chromium, nickel, vanadium, cobalt, etc. There are finally certain materials which are introduced into the metal during its process of manufacture in such a manner and in such quantities as to produce certain results and then be more or less completely eliminated. Such are, for example, aluminum, magnesium, cerium, uranium, and titanium. Of these more will be said later. Our primary interest lies in the compounds involving carbon and iron, it being, however, clearly understood that the formation, character, and stability of these compounds may be affected by the presence of the other elements above referred to. Because of this we shall at first deal with ferrous materials where the amount and character of the impurities are such as not to affect to any considerable extent the iron-carbon compounds.

Factors Affecting the Structure of Iron Alloys

The character of the iron-carbon compounds in all ferrous materials depends on three factors which we shall consider in succession. The first of these is the ratio of the carbon content to the iron content. The second is the effect of the processes which take place during the passage of the ferrous material from the liquid state to the solid state, the exact meaning of the terms "liquid state" and "solid state" being more fully explained later. The third is the mechanical, thermal, and chemical treatment of the material after it has reached its solid state.

As regards the chemical constitution of iron-carbon compounds, it is important to understand that as far as we know only one such compound can be formed and that is the carbide of iron, the chemical formula for which is Fe_3C. This compound consists of 6.6 per cent carbon and 93.4 per cent iron and is usually called "cementite." It would appear, furthermore, that in some way or other only a certain proportion of the iron will under our present conditions of manufacture take up the carbon necessary to produce cementite, no matter how much carbon may be actually present, the remainder of the iron retaining its freedom. In this way, and as a result of the interaction of such agencies as heat, solid solution, etc. a series of iron-carbon compounds are produced which, with essentially the same chemical composition, exhibit different characteristics. These compounds have been given special names, such as austenite, martensite, troostite, hardenite, sorbite, pearlite, etc. The exact meaning of these terms and the properties of the bodies thus denoted will become clear in the course of this series of articles. These bodies may pass from one into another when subjected to certain influences, especially heat.

If the structure of an iron alloy depended merely on its chemical composition, cementite and iron in their various combinations would explain it entirely. As a matter of fact, however, there are other factors besides chemical composition which must be taken into consideration. The first is that iron may occur in at least three forms, depending on the heat treatment to which it has been subjected. This happens with a good many materials such as sulphur and phosphorus and is called "allotropy."[1] More will be told about it in the chapter on The Crystalline Structure of Steel.

The next factor affecting the structure of iron alloys is that the combination of cementite and iron may take a number of forms, even when the content of carbon in the total mass remains constant. This is again a condition very commonly encountered in chemistry, certain materials being stable at one temperature and decomposing or passing into other combinations at other temperatures. A very interesting instance of this has been utilized in the Mond process of making metallic nickel. A compound of nickel and carbon called "nickel-carbonyl" is formed at a certain range of temperature, 122 to 176 deg. fahr. It remains stable between these temperatures, but at about 392 deg. fahr., it decomposes into nickel and carbon monoxide, this reaction being used for obtaining a very pure form of nickel. Now iron, which as has been previously stated occurs in three forms, and cementite likewise form several combinations depending on the temperature at which the material is maintained and—what complicates matters still more—the rate of cooling from the molten state, or especially from some of the higher temperatures. In order to understand what happens to a piece of steel we have, therefore, to consider all of these factors.

With very few exceptions, all ferrous products used in engineering are made from molten iron or steel, and passage through the various temperature ranges from that of molten metal to practically room temperature determines their structure and to a very considerable extent their mechanical properties. For purposes of simplicity and completeness it may be well to consider first what happens to a pure metal like iron or copper when it passes through these various ranges.

Assume that we have molten iron (pure) at a temperature several hundred degrees above its freezing point and that the supply of heat to the molten metal has been cut off. The metal will then gradually lose its heat, this loss proceeding under ordinary conditions at a practically uniform rate until the temperature is reached at which solidification begins to set in. It is known that solidification consists in a rearrangement of the molecules, which at the instant of solidification lose the amount of energy that enables them to move about freely. This loss of energy is expressed in an evolution of heat, which stops for a while the further loss of temperature. As the heat evolved by the solidification of the first batch of metal is lost by conduction, convection, and radiation, the loss of a further amount of heat from the metal leads to the solidification of another part of the liquid bath, and this proceeds until the entire liquid has solidified, at which time the whole mass is supposed to be at the same temperature, which is the temperature of solidification for the given metal. It is important to note that when solidification proceeds in the manner described, i.e., gradually, the mass from the time at which solidification commences to the instant at which it is completed consists of a mixture of metal partly liquid and partly solid. It is, however, possible, in particular with liquids freezing at comparatively low temperatures such as water, to cool the liquid several degrees below the point of solidification, provided it is maintained in a state of rest. But if the liquid is then jarred, it will solidify practically instantly. This does not usually happen

[1] There is no universally accepted definition of allotropy. Professor Sauveur defines it as "suggesting marked and sudden changes in some of the properties of a substance occurring at certain critical temperatures, without any change of state or of chemical composition." Jeffries and Archer (p. 61) define an allotropic change as a change in atomic arrangement, and add that this definition should furnish a positive criterion of allotropy hindered only by the experimental difficulties involved in determining atomic arrangements at high temperatures.

with iron, so that the first-described process may be considered as fairly standard (for pure iron).

Ferrous materials such as gray cast iron, carbon steel, and alloy steel are, however, not pure metals but compounds consisting of more than one element, and the freezing of such compounds proceeds in a manner somewhat different from that for pure metals. It also depends to a large extent on whether the compounds of the metal form a solid solution in each other or not. We may consider first the case when no solid solution is formed, i.e., when the constituents separate completely on freezing. Assume that the molten bath consists of a metal of high melting point H and a metal of low melting point L. It is further assumed that H is preponderant in the mixture. As the bath reaches the temperature at which H, when present in the mixture, begins to solidify, a small amount of it will freeze, and it is important to bear in mind that, in the majority of cases, the melting point, or conversely the freezing point, of H when present in a mixture of metals such as H and L, is lower than that of H alone, decreasing with an increasing content of L up to a certain point. The freezing of even a small proportion of H will leave a bath containing a larger proportion of L with respect to H, and this, in accordance with what has just been stated, will tend to reduce the temperature at which the next batch of H will freeze. This process goes on until the temperature has reached a certain definite limit for the given alloy, at which time the residual bath containing both H and L will freeze without further separation of H out of the bath.

The essential difference between the freezing of the pure metal described previously and the freezing of the mixture described here is therefore that in the case of a pure metal the entire mass freezes at the same temperature though not at the same time, the temperature being maintained constant automatically by the interplay between the natural cooling of the metal on the one hand and the evolution of heat as a result of gradual solidification of the metal on the other. In the case of the mixture of the two metals here described, solidification proceeds over a whole range of temperature beginning with the temperature of solidification of H and ending with the temperature of solidification of what might be called a saturated (with respect to L) mixture of the two metals.

As has been shown above, the gradual freezing out of H continues until the liquid represents a mixture of H and L such as contains a definite proportion of these two elements. Then the mixture freezes as such without further separating out of H. Such a mixture is called a "eutectic" mixture, which means a mixture which is the most fusible or having the lowest freezing point that can be made out of the two given materials.

In metallurgy such processes are often represented by means of diagrams, and Fig. 1, which (through the courtesy of D. Van Nostrand Company, New York City) is based on one in Dr. Walter Rosenhain's book, An Introduction to the Study of Physical Metallurgy, page 91, is an ideal equilibrium diagram of a system of two metals which has a eutectic temperature but does not form a solid solution. The line XCA represents an alloy or mixture at some temperature, at which the investigation starts. The line AEB represents the lower boundary of that region in which the alloys are completely liquid and is called by the Latin name "liquidus," the abscissas of the curve referring to the proportions of the metals in the alloy. The line CED represents the upper boundary of temperatures at which the alloy is completely solid. In the case of a simple system of two metals such as is described here, CED is a straight line and extends from XA to ZB. In more complicated systems it may be a curve or may extend over only part of the distance between the two limit ordinates. This line is called the "solidus" and the region between AE and EC on one hand and BE and ED on the other represents proportions of H and L which at the given temperatures are partly solid and partly liquid. It will be noticed that the point E lies both on the solidus line and on the liquidus curve, which would indicate that at the composition corresponding to E the metal solidifies throughout at the same temperature. This, as has been shown above, happens with the eutectic residue of H and L.

The solidification generally discussed above, namely, that of a mixture of two metals H and L which are supposed to form a system having a eutectic temperature but not producing a solid solution, may now be considered in connection with the diagram of Fig. 1. Had we had H alone it would freeze completely at the temperature shown by the straight line APM. Since, however, we have a mixture of the two, the freezing will proceed in the following manner: The metal will remain entirely liquid until it reaches the liquidus line AE at Q. Then a certain amount of H will freeze and this will increase the percentage of L in the liquid mixture from $O.Q$ to $O.R$, but at $O.R$ the metal freezes at a lower temperature r. At that temperature a sufficient amount of H will have frozen to increase the percentage of L to $O.S$, and the freezing temperature will become s. The next step will carry the percentage of L to $O.T$ and the corresponding freezing temperature to t, and this will continue until the temperature CE is reached, which is the lowest temperature at which the mixture of H and L can freeze and corresponds to the eutectic composition containing y per cent of L in the liquid mixture. From there on the freezing will proceed without change of temperature or of composition of the liquid metal, i.e., in the same manner as if it were a pure metal, the line CED being parallel to APM. It should be understood, of course, that the steps QR, RS, ST, etc. which are shown in the diagram as large distances

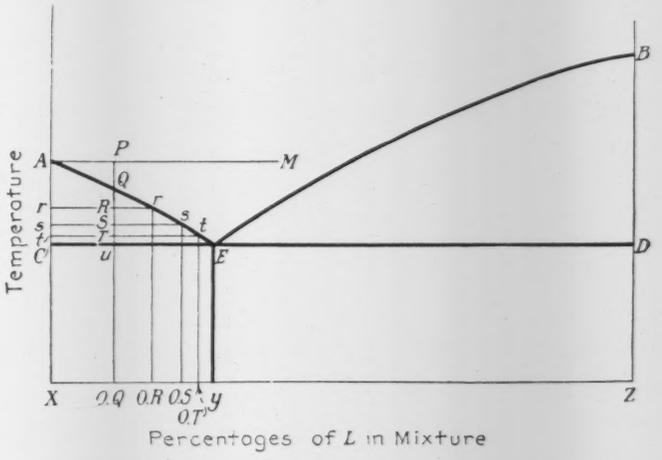


FIG. 1 IDEAL EQUILIBRIUM (CONSTITUTIONAL) DIAGRAM OF A SIMPLE BINARY EUTECTIFEROUS SYSTEM

are really infinitesimal ones, the process being a practically continuous one instead of, as shown here diagrammatically, divided into three or four steps. In the case of alloys forming solid solutions the liquidus and solidus have the meaning explained in connection with Fig. 1, but the shape of the curves is entirely different. Samples of such curves will be found, for example, in Fig. 33 on p. 98 and Fig. 34 on p. 99 of Dr. Rosenhain's book cited above.

This matter of freezing of metals has a very practical importance in many ways. As an example of this the case of steel ingots will be considered here, particularly important because the great majority of the products used in engineering begin as an ingot—to be forged, hammered, rolled, drawn into the final shape, etc. Moreover, in particular reference to rolled and drawn products, it has been found that in drawing and rolling the qualities of the ingot are distributed throughout the length of the product, so that whatever metal there may be, for example, in the inside core of the ingot will invariably affect the structure of the inside core of every beam, channel, or rail rolled from that part of that particular ingot.

Steel ingots in the conventional system of manufacture are made by pouring molten metal into stationary steel or cast-iron molds, the size of the ingot varying in ordinary practice from about 6 in. by 6 in. by 48 in. for tool and special alloy steels to huge blocks weighing many tons for gun forgings. The majority of commercial carbon-steel products are made, however, from ingots varying from, say, 16 in. on the side to about 48 in. on the side and about 72 in. long, although the larger ingots are cast in lengths up to 14 ft. The first molten metal teemed into the mold rapidly freezes, because of the contact with the cold mold wall. On freezing it contracts and draws away a little from the mold. It also gives up some of its heat (and some of the heat of the metal teemed subsequently into the mold) to the mold itself, causing the latter to heat and expand, as a result of which a certain air space is formed between the outer wall of the ingot and the inner wall of the mold,

hindering to some extent the transfer of heat from the ingot to the mold. For various practical reasons, steel is teemed from the ladle into the molds at a fairly rapid rate from, say, $1^1/_2$ tons per min. in the case of gun-forging ingots to 3 tons and even higher for ordinary steel products. With the present large heats (up to 100 tons per ladle) and the urge to attain the largest possible production, fast pouring is desirable because it makes freezing in the ladle nozzle less likely and permits getting through with the heat quickly. As a result of it, however, the mold is filled very rapidly. How does the freezing of the metal proceed then? Obviously, as has been noted above, the metal in immediate contact with the mold wall and to a small depth therefrom freezes very rapidly. But the layer next to it can lose heat only through the outside shell of the ingot which is itself very hot and therefore does not take up the heat easily from the molten steel. Moreover this shell can lose its heat only by giving it up to the mold and stool. (The ingot mold is open at the top and bottom and sits on a heavy cast-iron base called a "stool.")

But as has been noted above, the transfer of heat from the ingot to the mold is somewhat slow, because of the presence of the intervening air spaces. Therefore the cooling of the metal in the interior of the ingot proceeds rather slowly, and, as a matter of fact, if a hole were drilled into the side of a five-ton ingot half an hour after it was cast, molten metal would "bleed" out of the hole.

Now, if molten metal chills slowly it will chill in the manner described above; that is, first the constituent having the highest melting point will separate out to some extent, leaving a material rich in constituents having the lower melting points. These will have a lower melting point than the first batch because of the greater content of the alloying elements, and this process will continue until the eutectic mixture of the higher-melting-point constituents and the lower-melting-point constituents has been reached, whereupon the freezing of the alloy will continue at a constant temperature equal to the freezing temperature of this eutectic mixture.

How will this affect the resulting steel in the ingot? Commercial carbon steel has for its main constituents iron and carbon. It also contains, however, such materials as oxides of iron, phosphides and sulphides, silicates, and possibly manganese phosphide and sulphide. All of these have melting points considerably lower than that of the iron-carbon constituents, and as a result of the selective process of freezing described above they are gradually displaced to the last period of freezing in respect to time. But because of the method of freezing of an ingot, which proceeds from the outer shell inward, they are also displaced toward the central part of the ingot, which is therefore often richer in these impurities than the outer parts of the ingot. This process of concentration of some of the constituents of a steel in a given part is called "segregation." It is very undesirable, particularly in products subject to vibrational or alternating stresses, because the particles of segregated impurities not only do not contribute anything to the strength of the part of the metal in which they are embedded, but apparently on account of their irregular shape act somewhat like the notch in the notch impact test, introducing a grave weakening of the mechanical strength of the material. (Compare paper by J. P. Snow entitled Some Features of the American Rail Situation, before the Sixth Congress of the International Association for Testing Materials, vol. 2, pt. 2, paper X9.)

Allotropic Modifications of Iron

We may now return to the subject of allotropic modifications of iron. Pure iron in its normal condition is extremely ductile and possesses magnetic properties. It is called "alpha" ferrite or alpha iron. Upon heating this alpha iron to a little above 1400 deg. fahr. which corresponds to the critical range Ac_2, the iron becomes practically non-magnetic and is then known as "beta" iron. If it is further heated to a temperature above the upper critical range Ac_3, another change occurs producing "gamma" iron, which is somewhat softer than the beta iron. An understanding of this subject of allotropic modifications will assist in understanding the formation of the various constituents of steel. This latter also involves the subject of solid solutions. To understand this one may consider the interaction between salt and ice. When these two substances are placed in contact with each other under suitable conditions of temperature the salt and ice merge into each other, and so pass from the state of two separate substances or of mechanical mixture into that of one substance or brine solution. Here, however, the solution is a liquid, but the same process of intermixture may take place with the resultant being solid instead of liquid. In fact, a solid solution may be pictured as a homogeneous union of two or more substances in indefinite proportions, this union persisting in the solid state and being so complete that the individual substances cannot be distinguished under the highest-powered microscope. Chemical combination is not implied since a new compound would then be formed and the separate constituents would cease to exist as such, as they do in solid solutions.[1]

It has, however, been shown above that where iron and carbon are present, carbon in amounts not in excess of a certain limit may unite with iron to form a carbide called "cementite," and that all carbon and iron in excess of that which goes into cementite stays free.

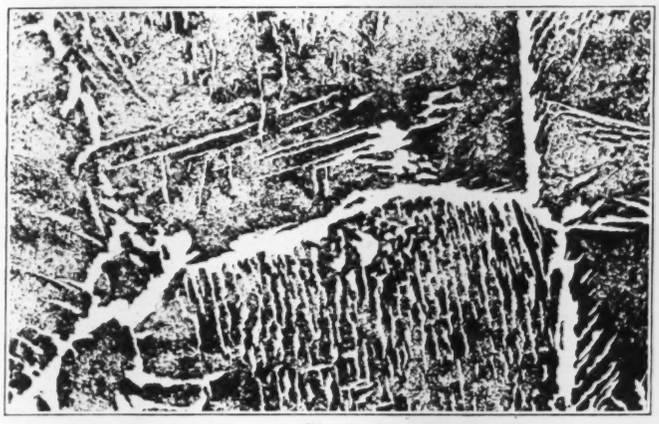
When pure iron undergoes its various allotropic transformations (the existence of the alpha and gamma iron is certain, and enough evidence is available to make the belief in the existence of the beta iron reasonable), there occurs merely a rearrangement of the iron molecules themselves, which means movements through comparatively small distances and hence requires but little time. If, however, the same changes occur in iron containing carbide of iron, such as cementite, the carbide molecules have to change their places, and this means a fairly large movement. The process may be carried out in two ways, either slowly or with extreme rapidity. If the process is carried on slowly within certain ranges of temperature, cementite forms a mechanical mixture with a definite amount of ferrite so that the resultant will contain approximately 0.89 per cent carbon. This mixture is called "pearlite," because usually it consists of interstratified bands of ferrite and cementite having an appearance under the microscope somewhat like that of mother-of-pearl. If, however, the cooling takes place with great rapidity, as, for example, by quenching, and the carbon content is sufficiently high, traces of the undecomposed gamma solid solution remain as white structural streaks running across the needle-like general mass. This structure has received the name of "austenite," which is defined by the International Association for Testing Materials as the gamma-iron solid solution when preserved as such down to ordinary temperatures; which may happen either as the result of quenching or because of the presence of a third alloying element.

Under certain conditions austenite decomposes into a needle-like, crystal-like substance which is called "martensite." Some investigators claim that under certain conditions of quenching there is produced martensite of composition 0.89 per cent carbon which is structureless and is desirable in quenched steels of certain compositions, such as cutlery steel, where the presence of a definite martensitic structure would indicate overheating. Such structureless martensite has been called "hardenite." It is always produced under such conditions that its carbon content is approximately 0.89 per cent, eutectoid ratio. Quite recently (cp. *Revue de Métallurgie*, Feb., 1925) a new theory of the formation of martensite has been proposed by the Japanese metallurgist Kotaro Honda, who denies that martensite is a product of degeneration of austenite.

Fig. 2 shows martensite as it appears under ordinary magnification of 100 diameters and Fig. 3 shows it under a magnification of 1840 diameters. Martensite is very important as it is the hardest constituent of hardened steels. It is due to its presence that quenched steels are so hard. It varies widely in the details of its structure, but usually has a needle-like (acicular) appearance, although at times the needles may be exceedingly minute.

Of late a view has been offered (by Francis F. Lucas) that it is the distribution of iron carbide in a highly dispersed state that is one of the contributing factors to hardness, if not the chief factor. According to this view the transformation to martensite marks in its early stages a very rapid precipitation of this constituent alloying with iron in some other allotropic form than the gamma state.

While it has been stated above that martensite usually appears under a microscope in the form of needles, it is also found with a decidedly granular appearance. This may be due either to partial decomposition to "troostite" (see below), or to the fact that the needle showing the regular structure is sectioned on a plane almost parallel to the plane of a line structure.



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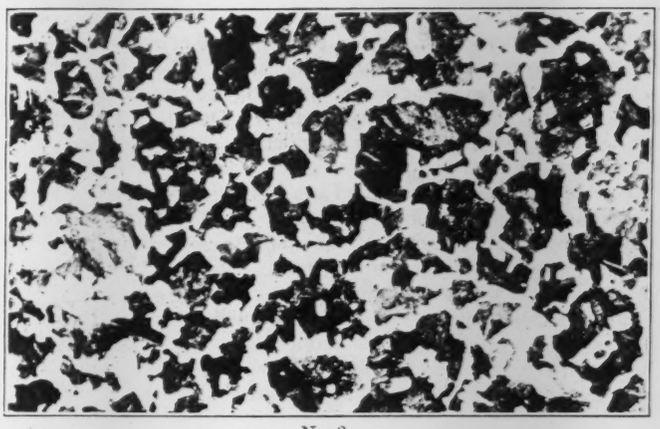

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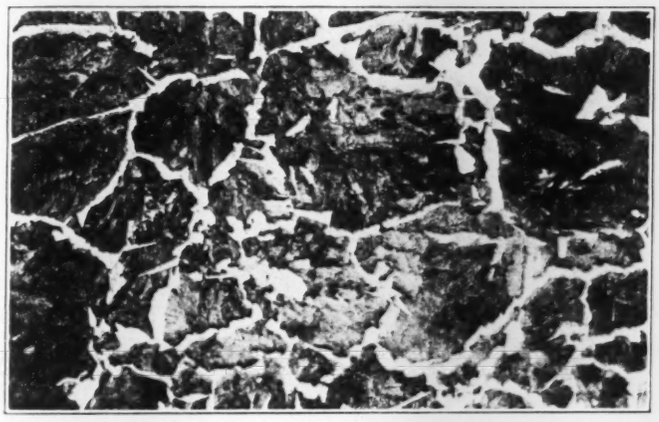

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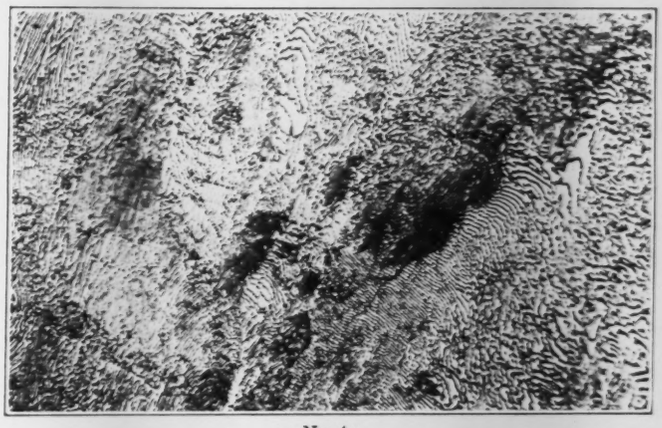

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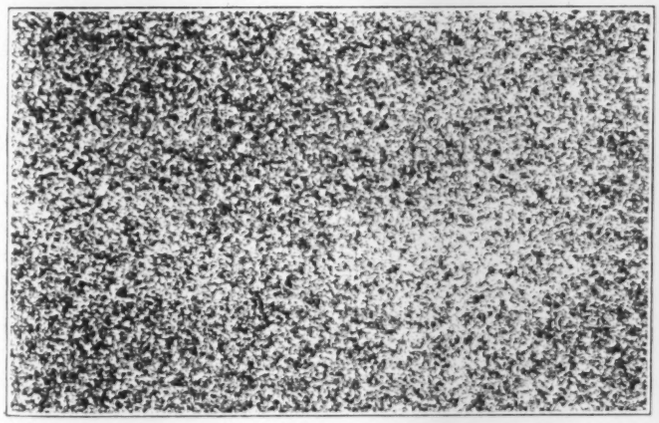

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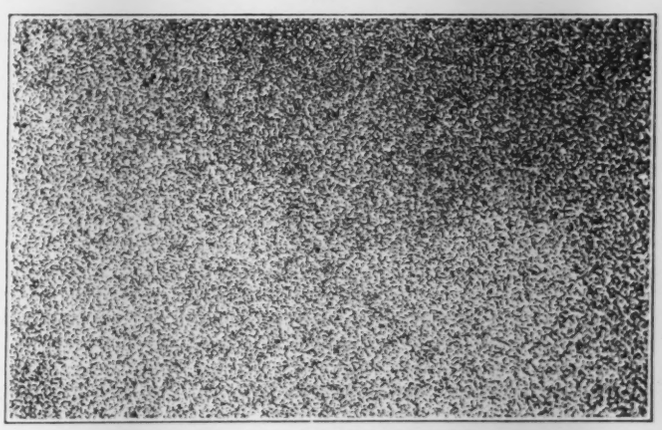

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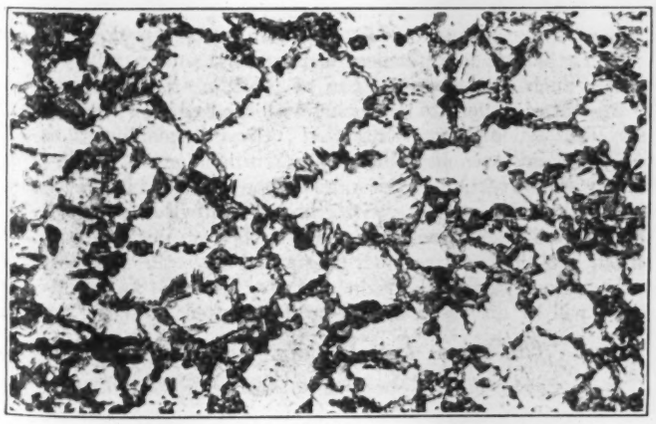

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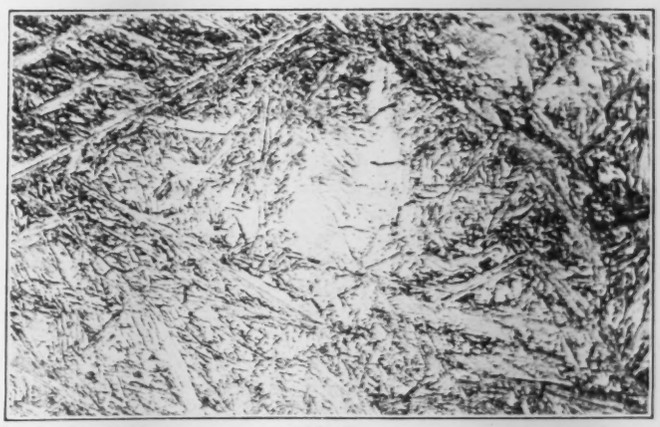

No. 8

FIG. 2 PHOTOMICROGRAPHS OF STEEL AND ITS CONSTITUENTS

No. 1, large-grained steel casting, magn. 100 diameters; No. 2, small-grained steel casting, annealed magn. 100 diameters; No. 3, pearlite, magn. 100 diameters; No. 4, pearlite, magn. 500 diameters; No. 5, sorbite magn. 100 diameters; No. 6, sorbite, magn. 500 diameters; No. 7, martensite-trootsite, magn. 100 diameters; No. 8, martensite, magn. 500 diameters (cp. for martensite Fig. 4.) (Courtesy of Union Carbide and Carbon Research Laboratories, Long Island City, N. Y.)

It is shown above that austenite and martensite form in rapidly cooled, i.e., quenched, carbon steels. If the rate of cooling is somewhat slower, the resultant structure is different. The edges of the martensite grains, more particularly where they border upon ferrite in steels containing less than the eutectoid proportion of carbon (0.89 per cent), show rounded or woolly outlines. This constituent on etching gives a very dark appearance, is called "troostite," and may be regarded as a further step in the degradation of austenite into ferrite plus pearlite (see Fig. 4). Troostite is a good deal softer than martensite and may be obtained either directly by a suitable rate of cooling or from martensitic steel (i.e., quenched steel) by reheating to a suitable temperature. This broadly explains why the so-called tempering—of which more will be said in the chapter dealing with heat treatment—reduces the hardness of quenched steels. When the rate of cooling is slowed down still more as compared with that in the previous operation, or the temperature of reheating raised, the decomposition of austenite is carried still further and a constituent obtained which is devoid of any visible detailed structure under the highest available magnifications; moreover it does not etch to such a deep color as troostite and does not have its peculiar rounded outlines. (See Fig. 2, Nos. 5 and 6.) This constituent is called "sorbite," but some metallurgists claim that it is simply a variety of pearlite and that the dividing line between pearlite and sorbite is simply a question of microscopic power. It may be mentioned by the way in this connection that the names austenite, martensite, troostite, sorbite, and some others have been given to the various constituents of steel in honor of the founders of the science of metallography. Rosenhain[2] points out that as between martensite and troostite on one side, and pearlite and sorbite on the other, there is a very important distinction: the two former are found essentially in steels quenched from temperatures above the line *PSK*, this line being the lower limit of existence of the gamma-iron phase (Fig. 5), while the latter are only met with if the rate of cooling through that temperature has not been unduly accelerated. Troostite is most readily obtained by oil quenching from temperatures just above *PSK* or 700 deg. cent., or by water quenching while the steel is actually in the critical range Ar_1. Rapid air cooling of steel specimens from temperatures above Ar_1 is sufficient to produce sorbite, which merges into pearlite as the rate of cooling is decreased.

An interesting utilization of the metallurgist's ability to produce the desired structure in steel may be seen in the manufacture of the so-called "sorbitic" rails. From what has been said above, it would be reasonable to suppose that sorbite lying between martensite and pearlite would be softer and tougher than martensite but harder than pearlite. It would therefore be of advantage for materials subjected to stresses at the same time as wear, such as, for example, rails and railroad wheel tires, and sorbite production has been applied to these materials in the Sandberg process, which consists of heating the steel to a temperature above the critical point and then cooling it so slowly that the martensitic condition is not retained and yet sufficiently rapidly to offset the pearlitic stage's being reached. The cooling is done by blowing air or steam on the heated steel. Tests have shown that fully treated steel had a breaking stress of 76.4 tons per sq. in. as compared with 57.32 tons for steel cooled in the atmosphere.[3]

It has been shown above that a mixture of ferrite and cementite in such proportions as to constitute pearlite contains 0.89 per cent carbon. Such a steel is known as a "eutectoid" steel, eutectoid being a Greek word meaning "most fusible" (the reason for giving it this name appears elsewhere). Steels containing less than 0.89 per cent carbon are also built up of ferrite and cementite, but some of the ferrite is not mixed with the cementite to form pearlite and is therefore free. Such steels are called "hypo-eutectoid," hypo in Greek meaning "under," and indicating that the steel contains less than the theoretical limiting carbon content.

When the carbon content exceeds 0.89 but is less than, say, 1.7 per cent, there is more cementite present than can mix with the ferrite. Such steel consists then of pearlite with free cementite, the amount of cementite increasing with the carbon content. Such steels are called "hyper-eutectoid" (hyper meaning "above"). Finally a point is reached when the iron is no longer capable of combining with the carbon, and if more carbon is present in the material than the iron can combine with, this carbon will be trapped when the iron solidifies and will be present in the iron in the form of free carbon. In the constitutional diagram, Fig. 5, this is represented by the region lying to the right of *E*.

This will be discussed in a separate chapter.

Fig. 3 Development of Martensitic Needles at the Grain Boundary of Austenite. Magnification 1840 Diameters

(From paper in Transactions of The American Society for Steel Treating, vol. 6, no. 6, December, 1924, by Francis F. Lucas; published by courtesy of the author of the paper and the Western Electric Company, New York City.)

Fig. 4 Nodular-Type Troostite Formed by the Direct Decomposition of Austenite to Troostite. Magnification 1360 Diameters

(From paper in Transactions of the American Society for Steel Treating, vol. 6, no. 6, December, 1924, by Francis F. Lucas; published by courtesy of the author of the paper and the Western Electric Company, New York City.)

The Iron-Carbon Equilibrium Diagram

The curves of Fig. 1 represent an ideal equilibrium diagram of a simple binary eutectiferous system. The iron-carbon system, however, has a somewhat more complicated diagram, of interest not only because of the importance of iron-carbon alloys, but also because more study has been devoted to this diagram than to that of any other metal or alloy.

The diagram of Fig. 5 is reproduced from a report of Committee 53 on the Nomenclature of the Microscopic Substances and Structures of Steel and Cast Iron, presented by Professors H. M. Howe and A. Sauveur to the Sixth Congress of the International Association for Testing Materials (New York, 1912, paper II–7, p. 6). This diagram extends only to a carbon concentration of 5 per cent, which is the practical limit of carbon found in iron alloys. (Experimentally, alloys with higher carbon content have been prepared, however.) It deals with a system which differs from that shown in Fig. 1 in that it forms a solid solution. Some lines have been added to the original diagram.

It appears from this diagram that all metal above *ABC* is liquid, the line *ABC* being the liquidus of the diagram. All material below *AED* is solid, the limit of solid solubility of cementite in iron lying on the point *E* or at about 1135 deg. cent. The point *B*

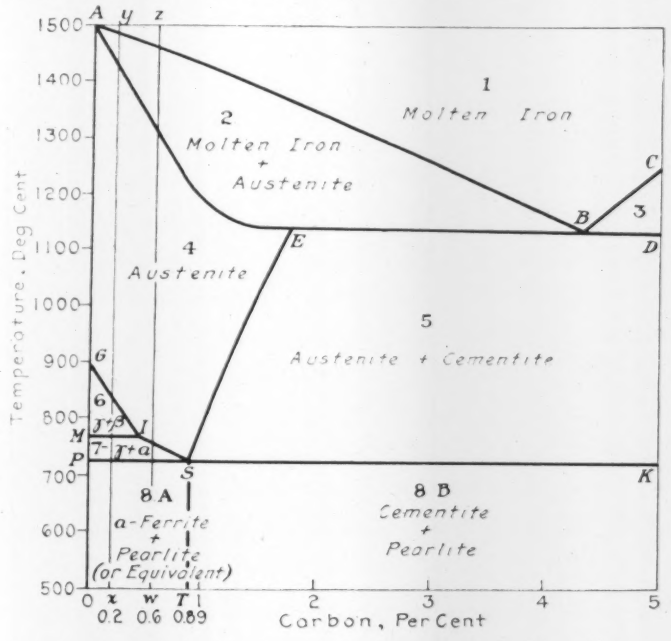

FIG. 5 CONSTITUTIONAL DIAGRAM OF THE IRON-CARBON SYSTEM

lying on both the liquidus and the solidus is the eutectic point, in this case that of the solid solution of γ iron with cementite.

The line *ES* shows the limit of solid solubility of cementite in γ iron. There are two features about it worthy of notice: one is that it slopes downward toward the low-carbon end of the diagram, which would indicate that the amount of cementite which γ iron can retain in solid solution decreases with falling temperature. The other feature is that the line *ES* does not extend to the base of the diagram, due to the fact that γ iron does not exist in a state approaching equilibrium below the temperature indicated by line *PSK*.

Dr. Walter Rosenhain in the constitutional diagram of the iron-carbon system on page 161 of his Introduction to the Study of Physical Metallurgy, adds a line shown in Fig. 5 as *ST*. To the left of this line and below *PSK* the metal consists of iron and materials of degeneration of austenite, which, as has been stated above, depending on the rate of cooling or thermal treatment, may be martensite, troostite, sorbite, or pearlite, which are varying arrangements that had been explained above. (In the original diagram this is designated as α ferrite and pearlite; as other constituents than pearlite may be also present, it is marked in this diagram α ferrite + pearlite, or equivalent.)

To the right of *ST* the metal may consist of cementite + pearlite with or without free graphite in either globular or flake form, depending on the factors discussed elsewhere (see chapter on Cast Iron and Its Derivatives). But on the line *ST* the metal consists of pearlite only as this line corresponds to the eutectic composition. Because of this the point *S* may be called the "eutectoid" point, and the body formed along the line *ST* is a "eutectoid," which means similar to "eutectic."

To give an idea of the information that a diagram of the kind shown in Fig. 5 may supply, steel containing 0.2 per cent carbon may be considered. It may be mentioned, however, in this connection that this discussion should not be taken as completely covering the subject; more information on the same subject will be contained in the second and third chapters, dealing respectively with the crystalline structure of ferrous metals and the thermal treatment of ferrous metals.

At a temperature of 1500 deg. cent. indicated by the point *y*, the metal is entirely molten. Beginning with the point where *yx* crosses *AB*, the metal begins to solidify, so that between that point and the point where *yx* crosses *AE* we have a mixture of molten iron and austenite, the solidification proceeding in a manner somewhat though not absolutely similar to that indicated in our discussion of Fig. 1. From the point where *yx* crosses *AE* to the point where it crosses *GI*, the entire metal is solid and is a mixture of austenite (which is a solid solution of carbide of iron in gamma iron) and gamma iron. When the metal cools down to the temperature corresponding to the point where *yx* crosses *GI* (about 840 deg. cent.) a change occurs in its structure in that some of the gamma iron is deposited out in the form of beta iron. It may be repeated in this connection that some doubt has been expressed as to whether beta iron is a true allotropic modification of iron. This hinges largely, however, on the definition of what an allotropic modification is and need not be discussed further here. Dr. Walter Rosenhain, for example, believes that beta iron is a true phase of iron, intermediate between the gamma phase and the alpha phase (Introduction to the Study of Physical Metallurgy, 1923, p. 170). Beta iron exists only between the temperatures corresponding to the points where *yx* crosses *GI* and the line *MI*. Below that temperature all the beta iron is transformed into alpha iron, so that in the section between *MI* and *PS* we have a mixture of gamma-iron solid solution with a steadily increasing content in crystals of alpha iron. As the line *PS* is passed (about 750 deg. cent.) the gamma-iron solid solution is transformed into the eutectoid mixture of alpha iron and cementite (which is pearlite), so that the metal consists of alpha ferrite and pearlite.

We know, then, that this metal has three points of transformation: first, on crossing *GI* from gamma into beta iron, second, on crossing *MI* from beta into alpha, and third, on crossing *PS* from gamma-iron solid solution into pearlite. The line *wz* which corresponds to the steel containing 0.6 per cent carbon crosses only the lines *IS* and *PS*, so that instead of having three transformation points it has only two and does not pass at all through the beta phase. In a later chapter dealing with the subject of heat treatment, the practical importance of this difference of behavior of the two steels will become evident, and among other things it will be shown how use is made of the fact that the 0.6 carbon steel line crosses the *AE* line lower than the 0.2 carbon steel line. This is merely cited to illustrate the use to which the constitutional diagram may be put, and the subject will be discussed more fully in later chapters.

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[3] Sandberg Sorbitic Steel Rails. *Railway Gazette*, Dec. 30, 1921, pp. 991–993.

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Some Elements of Drafting-Room Practice That May Be Standardized

F. W. MING,[1] BROOKLYN, N. Y.

WHAT is the best method of representing screw threads on a bolt? If one were to refer to a textbook on engineering drawing, he would find that any one of the methods shown in Fig. 1 might be used.

But which of these is the best method, and why is there such a wide diversity in practice? In teaching machine drawing, which method should be emphasized?

A hundred such questions occur in the teaching of machine drawing, and because of the variety of methods employed a college course in machine drafting to be practical must of necessity include all those used by manufacturing firms. This, of course, is inefficient and there should be more definite standards to follow in a drawing course given to college students.

The fact that there are now several methods of representing the same thing indicates a vital need for the standardization of machine drafting. European countries have recognized this fact and the project of standardizing drafting has become with them a national affair. Pamphlets have been published showing remarkable progress in this endeavor. It is a logical procedure in a program for standardization to begin by standardizing the specification for a product before standardizing the product itself. With this idea in view, a list of 120 manufacturing firms was prepared and to each of them was sent a questionnaire and a blueprint on which their chief draftsman might easily check off the method they preferred in representing the machine elements specified. They were asked also to express their opinion as to the need of standardizing machine drafting.

The results were amazing. Replies were received from every firm to whom a questionnaire was sent. Extracts from the letters received are given below:

Standardization of drawing-room methods is very much needed and I hope that your endeavors along this line will at least be the means of getting the movement under way.

Assuring you that I shall be pleased to advise you further as to our methods should you see fit to carry this work on.

THE NEW DEPARTURE MANUFACTURING COMPANY.

Your letter of the 14th inst. in regard to standardized methods for drafting rooms was duly received, and we are pleased to state that we are quite anxious to coöperate with you and be of such assistance as we can in this standardization.

When a final decision is reached by you on the work now in hand we can assure you we should be much pleased to receive a copy.

THE KEMPSMITH MANUFACTURING CO.

Your attempt to promote the standardization of the drafting-room operations is commendable and we shall be glad to lend you any assistance we can.

DIAMOND CHAIN & MANUFACTURING COMPANY.

We assure you that we are very much interested in the matter of standardization of drafting-room methods, and we shall be very glad to know how this matter is progressing.

DE LA VERGNE MACHINE COMPANY.

We feel that you are engaged in a worthy work, and if we can be of any assistance to you, kindly call on us.

AMERICAN BRIDGE COMPANY.

Wish to advise that we are glad to coöperate with you along these lines, and that we are enclosing the questionnaire filled out as per your request.

LANDIS TOOL COMPANY.

We should be very glad to be informed from time to time of the progress you are making along the lines of standardization of drafting-room methods.

ATLAS BALL COMPANY.

We trust that this matter will be of aid to you in standardizing your own drafting methods, and if we can aid you in any other manner we hope you will feel at liberty to request us to do so.

U. S. NAVY YARD.

After the matter has had your consideration we should appreciate receiving a copy of the conclusions drawn.

S. W. CARD MANUFACTURING COMPANY.

We shall be pleased to receive your final decision on what you consider are the best methods.

BARBER-COLMAN COMPANY.

We wish you every sucess in this work and if we can be of any further assistance to you, do not hesitate to get in touch with us.

CONSOLIDATED MACHINE TOOL CORPORATION.

We shall very gladly furnish you with information at any time which may be of assistance to you in carrying on this work.

THE GEOMETRIC TOOL COMPANY.

We should be glad to go into this further with you if there are any points we have not covered.

B. F. STURTEVANT COMPANY.

We trust the information given you will be of assistance to you in your worthy undertaking.

THE CHARLES WARD ENGINEERING WORKS.

Not only were letters received but also a voluminous collection of blueprints and drafting-room forms. A preliminary study of these prints proved that a wide diversity of methods are employed to represent like machine parts. The most outstanding need for standardization is in drawing sheet sizes. A list of the sizes now in use is given in Fig. 2, together with a graphical layout of these sizes.

A tabulation of the checks on the blueprints which indicate the methods employed by the various drafting rooms shows that some methods are more generally used than others. The results of this study are most enlightening.

Fig. 1 shows several methods of representing screw threads of the V-type. The order of preference is as follows: *B*, *D*, *E*, *F*, *A*, *C*, *G*, *H*, *J*, *I*.

Fig. 3 shows various methods of representing tapped holes in plan view and in the order of preference.

Fig. 4 shows several methods of representing tapped holes in elevation and in the order of preference.

Fig. 5 shows three ways of representing a hexagon nut in elevation and in the order of preference.

Fig. 6 illustrates two different methods of showing the slot in a flat, fillister-head machine screw. Note that *B* is a direct projection of the elevation view, while *A* is a violation of theory. Method *B* is more popular than *A*.

Fig. 7 shows three methods of drawing arrowheads on a dimension line, arranged in the order of preference. Method *A* is more commonly used than *C*.

Fig. 8 illustrated the various styles and sizes of lettering put on engineering drawings and in the order of preference. Note that two general styles are given, the vertical and the inclined.

Fig. 9 shows various methods of specifying a finished surface and also parts that are to be finished all over, in the order of preference.

Fig. 10 shows two methods of dimensioning a cylinder. Method *A* illustrates the figures in a vertical position while in *B* the figures are placed horizontally. Of the two methods shown, *B* is preferred.

Fig. 11 illustrates two methods of dimensioning a machine part through which holes are drilled. Note that in method *A* the holes are specified by notes and that the location of the holes is a stepped dimension checked by an overall dimension. In method *B* each hole is dimensioned with extension and dimension lines. Method *A* is preferred.

Fig. 12 shows two methods of dimensioning a rectangular block through which holes are drilled. In method *A* all the dimensions are placed outside and the holes are specified by notes. In method *B* some of the figures are placed inside of the object and the holes are dimensioned by extension and dimension lines. Method *A* is unanimously preferred.

Fig. 13 shows two methods of placing a figure in a circle. Method *A* is preferred.

Fig. 14 shows two methods of dimensioning concentric circles. No. 2 was unanimously selected as the method preferred.

Fig. 15 shows two methods of placing figures in dimension lines. Note that in No. 2 the figures "9/16" are placed in a vertical position. No. 2 is preferred.

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FIG. 1 METHODS OF REPRESENTING SCREW THREADS

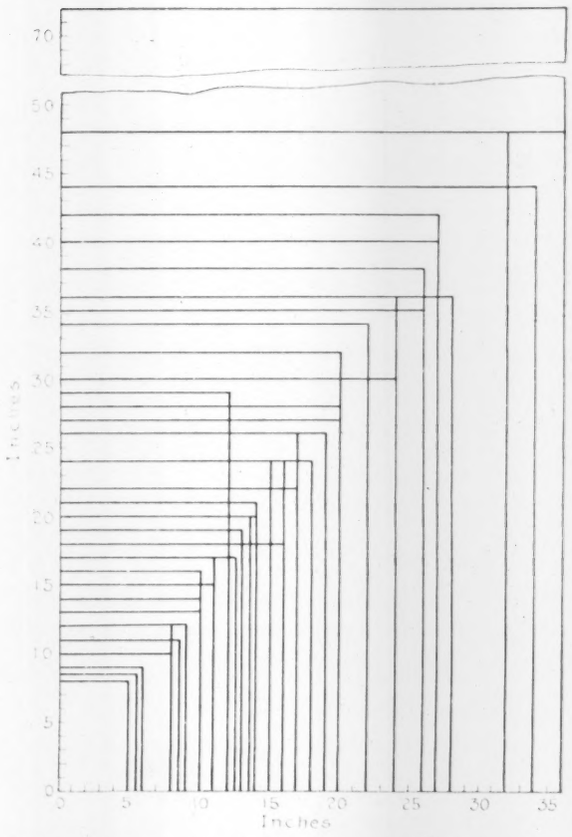

FIG. 2 COMPARISON OF DRAWING SHEET SIZES NOW IN USE

5 × 8	10 × 13	12 × 29	15 × 24	20 × 28	26 × 35	36 × 48
5½ × 8½	10 × 14	12½ × 17	16 × 24	20 × 32	26 × 38	36 × 72
6 × 9	10 × 16	13 × 19	17 × 22	22 × 30	27 × 40	
8 × 10	11 × 15	13½ × 20	17 × 26	22 × 34	27 × 42	
8 × 12	11 × 17	14 × 20	18 × 24	24 × 30	28 × 36	
8½ × 11	12 × 18	14 × 21	19 × 26	24 × 36	32 × 48	
9 × 12	12 × 19	15 × 22	20 × 27	25 × 36	34 × 44	

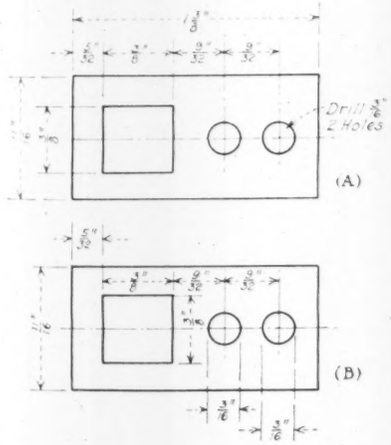

FIG. 12 METHOD OF DIMENSIONING A RECTANGULAR BLOCK THROUGH WHICH HOLES ARE DRILLED

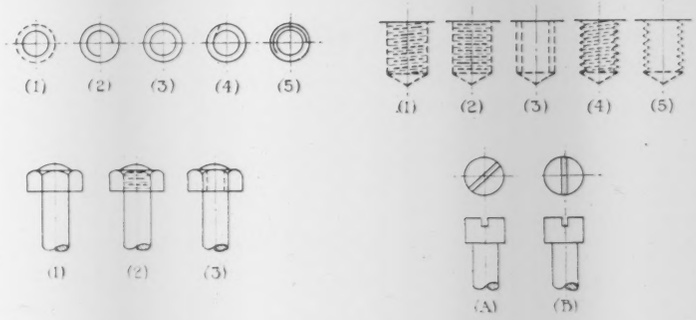

FIG. 3 (UPPER LEFT) METHODS OF REPRESENTING TAPER HOLES, PLAN VIEW

FIG. 4 (UPPER RIGHT) METHODS OF REPRESENTING TAPER HOLES, ELEVATION

FIG. 5 (LOWER LEFT) METHODS OF REPRESENTING A HEXAGON NUT

FIG. 6 (LOWER RIGHT) METHODS OF REPRESENTING THE SLOT IN A FLAT-FILLISTER-HEAD MACHINE SCREW

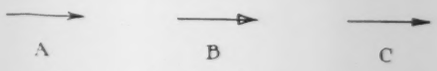

FIG. 7 METHODS USED IN DRAWING ARROWHEADS ON DIMENSION LINES

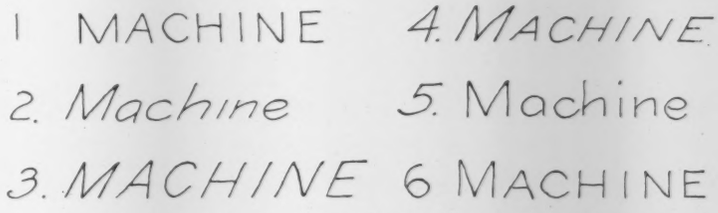

FIG. 8 STYLES OF LETTERING USED ON ENGINEERING DRAWINGS

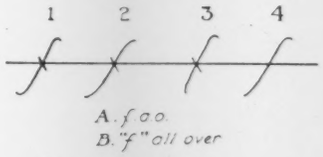

FIG. 9 METHODS OF SPECIFYING FINISHED SURFACES

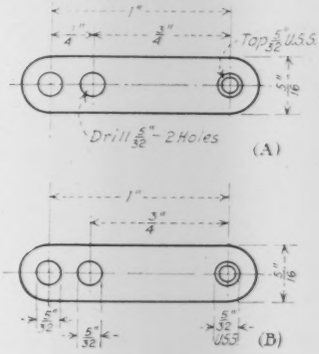

FIG. 11 METHOD OF DIMENSIONING A MACHINE PART THROUGH WHICH HOLES ARE DRILLED

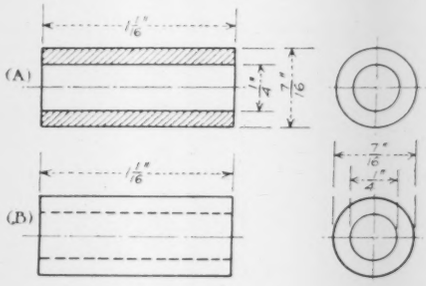

FIG. 10 METHODS OF DIMENSIONING A CYLINDER

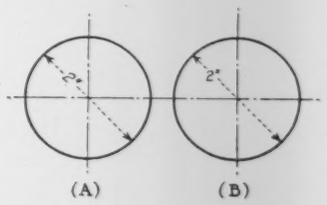

FIG. 13 POSITION OF FIGURE IN A CIRCLE

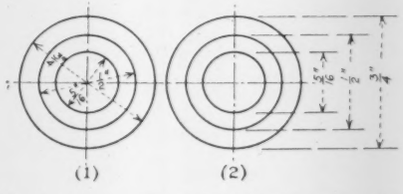

FIG. 14 METHODS OF DIMENSIONING CONCENTRIC CIRCLES

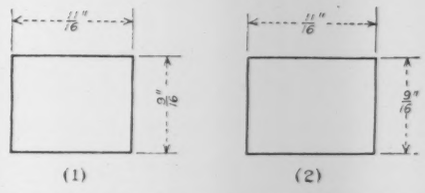

FIG. 15 METHODS OF PLACING FIGURES IN DIMENSION LINES

Fig. 16 shows two methods of projecting a line of intersection. No. 1 is a true projection of the cylinder in the drum, while No. 2 is a projection violating theory. Of the replies received, 30 per cent favored method No. 1. It is interesting to note that there is a tendency to stick to theoretical projection rather than to employ short-cut methods which violate theory.

Fig. 17 shows two methods of dimensioning the end of a rod that is chamfered. No. 2 is preferred.

Fig. 18 shows two equally preferred methods of placing the numerals in specifying angular dimensions. No. 2, however, has a slight advantage.

Fig. 19 shows two methods of dimensioning an area that has been section-lined. In method *A* the figures are placed in the section. A clear spot of course is provided to insure greater legibility of the figures. In method *B* the figures are placed outside of the section, but the extension line must of necessity be run through the section. Both methods are equally preferred, but method *B* has a slight advantage.

Fig. 20 shows two methods of projecting the arms of a pulley in a cross-sectional view. Method No. 2 is a true projection of the arms in the plan view. Method No. 1, however, is not a true projection but a violation of theory. Both methods are widely used, but No. 2 is preferred over No. 1 by about 25 per cent.

Fig. 21 shows two methods of dimensioning a slot about a center line. Method *A* is generally preferred.

A tabulation of the questionnaires which accompanied the blueprints indicates that there is a wide diversity in methods employed for specifying notes, changes, lengths, etc. For example: In answer to the question as to the limit of the length specified in inches, a majority of the firms stated 2 ft., but many of those replying indicated other limits such as 100 in., 36 in., 5 ft., 6 ft., 4 ft., 1 ft., and 25 in.

A great many different methods are now used for indicating a change in a dimension on a drawing. Most of the firms incorporate in the design of their standard drawing sheets a box in which all changes are recorded. References to the dimension in question are made either by number or letter, or by both.

Some firms place inch marks after each dimension, while others omit them entirely. The majority of them, however, employ the inch mark. It is generally understood that dimensions are not repeated for the same part, yet a study of the answers on the questionnaires shows that this is not the general practice.

With respect to the kind of transparent medium employed, a tabulation of the replies received shows that while tracing paper is gradually displacing tracing cloth, still the majority of the firms are using tracing cloth. Vellum is also used extensively.

It was formerly the general practice to put drawings of various details on a large sheet, from which they were later cut out. The present practice, according to the replies received to the questionnaire, is to draw details on separate sheets of paper, placing only one detail on a sheet.

The tabulated results of the answers to the questionnaire and blueprint are not conclusive, since the methods of a great many of the larger firms have not as yet been studied thoroughly.

One hundred and twenty firms have responded by supplying copies of their drafting-room standards and blueprints illustrating the practice they have adopted in their plants. These firms may be classified into the various industries as follows:

Machine Tools	Construction and Contracting
Electrical Apparatus	Steam Engines
Army and Navy	Railroads
Conveyors and Hoisting Machinery	Gas Engines
Ball Bearings	Automobiles

The 1200-odd blueprints that have been collected have been classified by assigning a number to each company. The following tentative outline has been prepared and each print is studied with this outline as a guide.

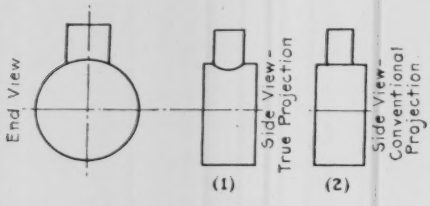

FIG. 16 METHODS OF PROJECTING LINES OF INTERSECTION

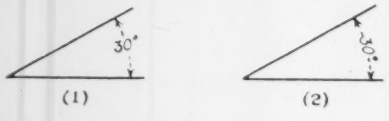

FIG. 18 METHODS OF DIMENSIONING ANGLES

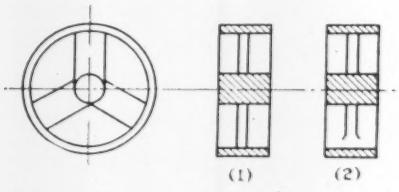

FIG. 20 METHODS OF PROJECTING THE ARMS OF A PULLEY

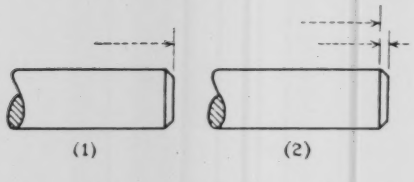

FIG. 17 METHODS OF DIMENSIONING THE END OF A ROD THAT IS CHAMFERED

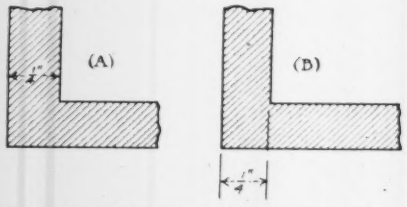

FIG. 19 METHODS OF DIMENSIONING A SECTION-LINED AREA

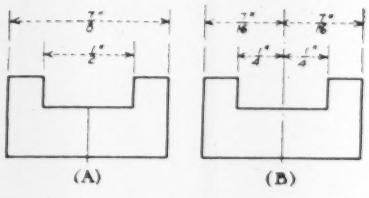

FIG. 21 METHODS OF DIMENSIONING A SLOT ABOUT A CENTER LINE

OUTLINE FOR THE STUDY OF BLUEPRINTS

I—FORMS

Medium-detail, tracing cloth, tracing paper, vellum, etc.; Sizes: royal, imperial, odd, etc.; Border rulings: margin; Title boxes, revision boxes, numbering, etc.; Layout of the sheet: grouping of the details; Pencil drawing or ink drawing.

II—LETTERING

Title, sub-title, note, numerals, bill of material, etc.; Title boxes, content, size, location, etc.; Style, vertical or inclined; all capitals or capitals with lower-case letters.

III—REPRESENTATION

Alphabet of lines; Views: number and arrangement, angle; Cylindrical parts; Symmetrical parts; Sectioning: theory, violations, etc.; Conventional breaks; Developed or bent surfaces; Machine fastenings; Gears: spur, bevel, worm, special; Cams: development, working drawings of cams; Keys; Pipes; Threads; Springs.

IV—DIMENSIONING

Lines: dimension, extension, leaders, etc.; Location of numerals; Arrows: shape, size; Shape and size dimensions; Location dimensions; Base-line dimensioning; Angular dimensions; Finish marks and notations; Fractions: position of dividing line; Placing of tolerances, limits, fits, etc.; Revisions and corrections; Not-to-scale dimensions: method of specifying; Fillets, radii, arcs, angles; Holes: drilled, reamed, cored, counterbored, countersunk, etc.; Specifying finishes: grind, lapped, chilled, hardened.

V—SPECIFICATIONS

Standard or purchased parts; Finished and stock materials, etc.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS

Preliminary Study of the Influence of a Rotating Cylinder on a Wing

DATA of experiments undertaken mainly as a result of certain work by Joukowsky, Bjerkness, and Ackeret at the Dutch Rijks Studiendienst, which corresponds to the Bureau of Standards in this country. The main problem to be solved was whether or not it would be possible to obtain increased lift from an airplane wing by building into its leading edge a rotating cylinder, and no attempt was made during the preliminary experiments to obtain drag or center-of-pressure measurements.

The rotor was driven by a small electric motor and tests were made with the opening between the cylinder and wing section either open or closed; a considerable increase of lift was obtained with gap closed. From data published it would appear that with the cylinder stationary and the slot closed the maximum lift coefficient has a value of 0.413 abs. and the upper critical angle is 4 deg. With the cylinder revolving at 3000 r.p.m. the lift coefficient is 0.522, and an increase in rotor speed to 17,000 r.p.m. increases the lift coefficient only to 0.527.

The general shapes of the curves are very similar to those obtained with the Handley-Page slotted wing, but the percentage of increase in the lift is not so great. So far there is no information as to the effect of the presence of the rotor on the L/D of a wing section. It appears likely that the shape of the nose which the rotor will necessitate may adversely affect the drag.

It is suggested that the rotor may be used for lateral control at or above the stalling angle. (*Flight*, vol. 17, no. 838/3, Jan. 15, 1925, pp. 30–31, abstract of an article by Dr. Ir. E. B. Wolff in *De Ingenieur*, Dec. 6, 1924, 2 figs., *e*)

Long-Distance Flights

A NUMBER of long-distance flights are planned for 1925 as a result of the performance of D'Oisy who flew from Paris to Tokio. The aim of the flights now projected is to determine the conditions necessary to organize aerial communication between France and its immense colonies in equatorial Africa. An attempt will also be made to establish a line between Dakar and Lake Chad. All the machines selected are of known types, equipped with several motors each. Among others selected for the Dakar flight are two Blériot machines each with four Hispano-Suiza 180-hp. motors. Each machine in flight order will weigh approximately 5500 kg. of which 1000 kg. is useful load, 1000 kg. fuel, and 250 kg. oil and cooling water. The useful load includes a crew of two pilots, a mechanician, a radio telegrapher, and 250 kg. of instruments, together with various accessories, provisions, and spare parts. The fuel corresponds to nine hours of flight or to a radius of action of 1300 km. (807 miles), and is carried in four tanks holding 250 liters (66 gal.) each. The first trip is to be from Paris to Dakar, across the Sahara, returning along the western coast of Africa over Smyrna. The second one will also be from Paris to Dakar, a distance of 4200 km. (2609 miles), but in a single flight. For this purpose a fast two-seater will be used, namely, a Bréguet-19 of the type used for D'Oisy's Paris-Shanghai flight but equipped with a Renault 480-hp. motor. It will carry 2000 liters of gasoline (528 gal.).

Mittelholzer the Swiss flier left Zurich on December 18 for a flight to Persia, a distance of about 5000 km. (3106 miles), but on December 28 was halted in Smyrna by Turkish authorities on account of failure to procure the necessary permission for flying over Turkish territory.

The article from which the foregoing particulars are taken reports a number of shorter-distance flights. (*L'Aerophile*, vol. 33, nos. 1–2, Jan. 1–15, 1925, pp. 7–9, illustrated, *g*)

[In this connection the New York *Evening Post* of March 18, 1925, in a special cablegram from London under the same date, reported that Alan Cobham had completed a flight of 17,000 miles to India and return without engine replacement. The plane was a De Havilland-50 fitted with a 230-hp. Siddeley-Puma engine. It is stated that there was not a single forced landing due to engine trouble, and that only twice on the flight was it necessary to make an external overhauling of the engine. The only things replaced were propellers.—EDITOR.]

The Croydon Airplane Accident

DISCUSSION of an official report of the Court of Inquiry appointed to investigate the fatal accident which occurred on December 24, 1924, near the Croydon airdrome to a D.H.-34 machine.

According to the author, the true causes of the accident were not brought out by the report, and the accident in his opinion was due to the use in commercial aviation of airplanes built during the war or of wartime design, which in the light of our present knowledge are not only obsolete but decidedly dangerous. The type of wing used throughout the war on every airplane, with perhaps the exception of certain types of Fokker fighting machines, has the peculiarity that when the tail of the machine is pulled down and the nose of the machine is pulled up to a certain point, the wing loses its lift. The machine drops its nose suddenly and dives until it has acquired sufficient speed to give the pilot control over it again. If the machine is stalled and nose-dives from anything below 1000 ft., it will hit the ground before the pilot can regain control. The special quality of the types of machines which can now be built with certain kinds of thick wings and with wings fitted with flaps as well as possibly with slotted wings, is that in the event of the nose of the machine being pulled up until the machine stalls, the machine will simply sink and begin to glide forward, but will not under any circumstances throw its nose down and dive.

According to the author, the U. S. Air Mail Service is experimenting now with various forms of wings which will prevent nose diving and permit slow landing.

The Royal Air Service has already in service four types of war machines with non-diving, slow-landing wings. Two of these are single-seat fighters, one is a two-seat bomber, and one is a general-service seaplane. All are capable of getting off at slow speeds with heavy loads, land slowly under perfect control, and cannot dive. They are apparently equipped with flap wings. (*The Aeroplane*, vol. 28, no. 7, Feb. 18, 1925, pp. 141–142, *g*)

Recent Developments in Aircraft Engines

THE most interesting part of this article is that dealing with the two engines of 500 and 800 hp., respectively, which were recently developed by the Packard Motor Car Company for aircraft service.

It is stated that the smaller engine develops 100 hp. more than the Liberty while weighing 140 lb. less. These improvements were made possible largely because of a new type of cylinder construction, original studies with regard to the loads that can be carried by bearings, reduction of the weight of the crankshaft accompanied by greater strength, and the compacting and lightening of the timing and accessory drive layout.

Before designing the new Packard engines a definite program was laid out. It was decided that the new engines were to represent a distinct advance in the art and that precedent should be disregarded when it was based on so-called common practice unsupported by well recognized and proved engineering limitations.

In other words, practically nothing was taken for granted. Even relatively unimportant parts of the engine received the closest possible scrutiny in an effort to obtain the maximum possible power output with the least possible weight and the greatest possible dependability. Time will not allow an explanation of the methods employed in all cases, but in general it may be stated

that when a problem involved stresses that would yield to sound engineering problems, such a solution would be acceptable, but when the design had been dictated merely by so-called good engineering practice, a more or less thorough investigation was made either by analysis, or by practical experimentation, or by a combination of the two, in an endeavor to ascertain the actual limitations.

A case in point is the matter of relation of bearing materials to allowable loads and speeds. This of course represents one of the oldest studies in the world of mechanics: volumes have been written on it. The arrival of aircraft engines, however, has thrown an entirely new light on the possibility of increasing the permissible speeds and loads, provided that certain essential requirements that have been uncovered by long experience with aircraft engines are observed. At this point it might be well to inject the statement that the foundation of any engine design is represented by its bearing layout, that the structure cannot proceed until this foundation has been laid, and that the structure will not be satisfactory if the foundation is poor. In other words, a fundamental principle of good engine design is to begin with exact knowledge of the loads to which the engine bearings are to be subjected, and to design accordingly.

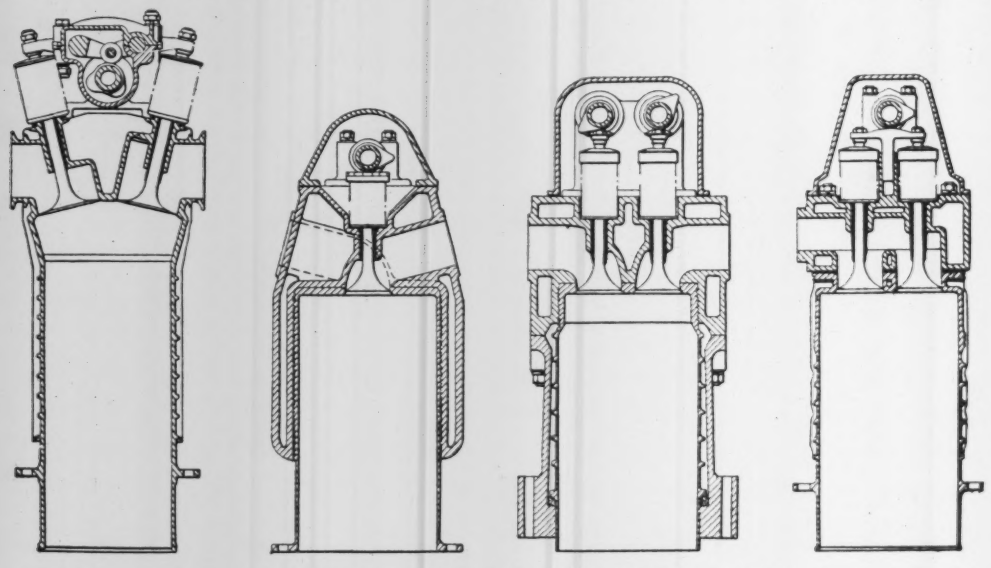

FIG. 1 A STUDY IN AIRPLANE-ENGINE CYLINDER CONSTRUCTION
(At the extreme left is the Liberty cylinder; the two central views show the aluminum-block construction with dry and wet sleeves, respectively; at the extreme right is the new steel cylinder.)

In aircraft engines the life of the connecting rod and the main bearings are the most important influences controlling the period between overhauls and should receive first consideration. On the other hand, if past practice is merely followed and a so-called "generous" bearing area is provided, we shall be overlooking two important considerations. One is that past practice in aircraft-engine bearings has not given altogether satisfactory results; the other, that we shall be prevented from using an important means of reducing the weight, namely, reducing the length of the bearings, and, consequently, the length of the engine. It will be necessary to digress for a moment to state that the length of an aircraft engine has not always been limited by bearing considerations for, in many cases, the closest spacing of cylinder centers possible with certain types of cylinder construction, rather than the length to be allotted to the bearings, has dictated the design.

In the investigation, failures of bearings were traced to fatigue of the babbitt lining that was produced by minute flexing of the backing of the bearing The importance of more rigid bearing backing was thus emphasized and it became evident that if the babbitt were prevented from flexing under load, far greater loads could be carried without flexing distress. It was then determined to run a series of tests on a bearing-testing machine, using various types of bearing metals, and in each case gradually increasing the speed and the load in an endeavor to ascertain what the bearing limitations actually were, granted that the two well-recognized requirements were complied with.

The first of these was that the bearing must not flex appreciably under load, and the second was that ample force-feed lubrication must be provided, not only to produce a continuous oil film but also to circulate a quantity of oil sufficient to insure the proper viscosity of the oil that maintains the requisite thickness of the oil film.

It was realized that, in the engines to be built, both these requirements could be controlled in the design and, once the comparative information had been obtained from the bearing-testing-machine tests, the data could be translated into the engine design. It was recognized, of course, that conditions in the bearing-testing machine were very much different from those obtaining in an engine running under its own power, in that the loads on the machine were concentrated uniformly in a fixed direction, whereas those on the engine were constantly changing, both in intensity and in direction. It is not claimed that the results of these tests throw any particularly new light on the subject of bearings. What was accomplished was the acquiring of knowledge along the desired lines without having to rely on the reported work of various investigators, each of whom conducted his tests with other apparatus, other materials, and other test conditions of speed, load, and lubrication.

A series of tests were then carried out to determine various elements affecting the life of the bearings, in particular, rubbing factors, and on this basis crankshafts were designed so that the primary critical speed would occur far beyond the operating range of the engine. The resulting shaft is about twice as stiff as the Liberty shaft, although the weight is approximately 30 per cent less. This was accomplished by the use of journals having comparatively large outside diameters but bored out through their centers, so that relatively great stiffness accompanied by light weight is provided. The cylinder construction is shown in Fig. 1 and its choice was based on two considerations: one that adjacent cylinders should be spaced as closely together as possible so that the bulk and weight of the engine as a whole would be diminished, and the other that the cylinder assembly should be as light as possible. Each block is composed of six individual cylinders attached to a single aluminum casting termed the "valve housing." The individual cylinder is composed of a drawn-steel sleeve welded to a forged combustion-chamber head machined completely, and having a headplate and a sheet-metal water jacket welded into place. Each cylinder is provided with four valves, short valve ports being formed integral with the cylinder. These valve ports are accurately hollow-milled on their outer surfaces; and the headplate is bored so as to form a press fit over the valve ports, the plate seating on shoulders so as to provide about $^3/_8$ in. water space above the combustion chamber. The cylinder head is provided with five bosses into which are screwed long studs for supporting the valve housing. The spark-plug bosses are formed integral with the combustion chamber. Steps in the manufacture of these cylinders are shown in the original article. The weight of the complete Model 1500 cylinder is 9.5 lb. and the cylinder develops nearly 50 hp.; the weight of the complete Model 2500 cylinder is 15.2 lb. and the cylinder develops nearly 70 hp.

The advantages of the new cylinder construction may best be studied by comparing it with the other designs shown. The first point in its favor is that it provides water circulation in close contact with all the heated surfaces, which is not the case with the closed-type sleeves shown in the two central views of Fig. 1. Another point in common with the first two designs is that the steel cylinder barrel is used as a wearing surface and carries the explosion loads down to the crankcase, which is not done by the dry-sleeve cylinder, in which the aluminum water jacket assists in withstanding the heavy loads.

Among other things, the author points out that with each ad-

vance in engine design important improvements in airplane design immediately follow; and these alternate steps typify the sound progress that is being made in aviation. Incidentally, the interrelated advances in the design of the airplane and of the engine result in continual improvements in airplane performance that, from a military standpoint, result in maneuvering qualities of a highly sensational nature.

As an example, the daring and highly skilled pilots composing the First Pursuit Group at Selfridge Field are engaged daily in maneuvers that would have been impossible a few years ago.

With airplanes that weigh complete little more than an engine of corresponding horsepower would have weighed several years ago, most astonishing performances are possible. For instance, such maneuvers included what amounts to a climbing tail spin, i.e., a vertical barrel roll, and several barrel rolls at the top of a loop, with practically vertical zooms for hundreds of feet. Needless to say, maneuvers such as these and the terrific acceleration that results from catapulting airplanes from battleships produce difficult problems in engine operation, particularly with reference to carburation. In this way progress in engine and airplane evolution adds new problems to be solved. (L. M. Woolson, Aeronautical Research Engr., Packard Motor Car Co., Detroit, Mich., in *The Journal of the Society of Automotive Engineers*, vol. 16, no. 3, March, 1925, vol. 16, no. 3, pp. 297–309, 19 figs., *dA*)

CORROSION

Surface Abrasion as a Potential Cause of Localized Corrosion

PREVIOUS work has indicated that most cases of surface corrosion are of an electrochemical character; for electrochemical action usually gives rise to soluble primary corrosion products, while direct chemical oxidation would generally produce an insoluble body *in situ* on the metallic surface, which would tend to obstruct further attack. Bengough has indicated that local abrasion—by causing removal of the obstructive film—may allow local attack, while von Wurstemberger has suggested that very severe corrosion may be occasioned by electric currents flowing between the bare abraded portion and the still encrusted area. An experimental investigation has been made regarding the existence of these currents. Sometimes they flow in such a direction as to localize corrosion on the small abraded portion, sometimes in the customary direction. But they are generally transitory, dying away soon after abrasion ceases. Moreover, the abrasion required to produce these currents must, in most cases, be sufficient to damage the metal by mechanical erosion also. In the case of the corrosion of zinc by hydrochloric acid, the wiping away of the black scum of residual impurities—lead, etc.—actually diminishes the rate of attack; the impurities, if allowed to accumulate, act as the cathodic members of the corrosion couples and facilitate the liberation of hydrogen. Vernon's statement that commercial (impure) zinc is attacked more slowly than some grades of much purer zinc, is, however, confirmed; probably "homophase" impurities (in solid solution) behave in the opposite mode to "heterophase" impurities (present as a separate phase). (Ulick R. Evans in a paper presented before the Institute of Metals March 11, 1925, and abstracted through *The Engineer*, vol. 139, no. 3611, March 13, 1925, p. 294, *g*)

Corrosion of Boiler and Condenser Tubes and Action of the Hot Wall

THE Corrosion Research Committee of the Institute of Metals in a report presented in October, 1923, to the Institution of Engineers and Shipbuilders, Newcastle-on-Tyne (compare MECHANICAL ENGINEERING, vol. 45, p. 542) laid stress on the fact that entangled air was a powerful contributor to corrosion. It has never been explained why entangled air accelerates corrosion. In the present paper this is explained by reference to a physical effect belonging to the same class and known as the Ludwig-Soret phenomenon.

In previous work the author found that when an electrically heated platinum wire was immersed in a stream of flowing water, it was often locally overheated, even at a comparatively low electrical current strength. An investigation has shown that when ordinary water was used which contained dissolved air, some gas was deposited on a given spot of the wire and the air bubble thus formed prevented the liquid from cooling. The adhesion of the air to the hot wire, probably to some spot of slightly higher temperature, was found to be so great that no practicable increase of the water speed could prevent it.

The following explanation of this phenomenon is suggested: As is well known, even in homogeneous moist air a new phase (liquid water) appears on every point where the temperature is below a definite value (the dewpoint). This implies that the partial pressure of the water is determined by the lowest temperature occurring. This is often designated as "the action of the cold wall." On the other hand, in a liquid containing air, or another gas, in solution, a new phase (gas) will appear on every point where the temperature is above a definite value (depending on the concentration and solubility of the gas). This implies that the partial pressure of the dissolved gas is determined by the highest temperature occurring. In order to have the analogy borne out as clearly as possible, this is designated as "the action of the hot wall." A number of experiments described in the original paper were carried out to demonstrate this action of the hot wall.

To counteract this obnoxious corrosion the following procedure is suggested:

1 It is evident that the surface of the metal must be as even or smooth as possible (the tube thickness as regular and the metal itself as homogeneous as possible). Any metallic projections from the surface are liable to act as centers for the formation of the gas phase. This conclusion, however, is not new, as from nearly every point of view in corrosion the smoothness of the surface is desirable. Unfortunately from the standpoint of the practical engineer, only little can be done in this direction.

2 It is obvious that the formation of an even sea-scale layer on the metal surface—at least if not too thick—must protect the tube in lessening the effect of any temperature differences that may exist in the metallic surface. This likewise conforms to full earlier experience, but little can be done, as it seems, in this direction.

3 If the tube surface is originally very smooth a high speed of the water is likely to be in opposition to the air precipitation, though probably in no way excluding it; on the other hand, if the surface is roughened, a very high speed will scarcely have any beneficial influence.

4 The only radical means to avoid corrosion will be to remove the possibility of air precipitation in using a water devoid of air. This, likewise, is no novel conclusion; on the contrary, practical means of removing the air content of water is an old desideratum. Here, however, the chemical method is out of the question, as the nitrogen that is then left unremoved will exert the same influence of local superheating. The physical method used hitherto, involving the combination of heating and vacuum, signifies a considerable complication. It is therefore very fortunate that the elucidation gained as to the main cause of this corrosion will at the same time offer the rational remedy, "elements beaten with their own arms" (*elementa suis armis devicta*) being a sound principle. As a matter of fact, the action of the hot wall may be taken advantage of in order to remove the air, or other gases, at places where it causes no harm.

The most effective way of removing moisture from air probably is to let the air pass over a body of very low temperature (as that of liquid air); the action of the cold wall then causes a removal of every trace of water. Analogously, we may conclude that a very effective way of removing air from liquid water must be to let the water pass over a body of very high temperature; the action of the hot wall will then probably cause a very energetic air removal. To test the truth of this conclusion a series of experiments were carried out as described in the original paper and an experimental apparatus is described which permits the removal of the greatest part of the air content of the water. On the average 93.8 per cent of the energy used in air separation is recovered in the heating of the water. It should be understood, however, that this applies, however, to an elaborate device.

The second section of the paper discusses segregation in molten iron occurring previous to solidification, and the author ascribes certain forms of segregation to the same Ludwig-Soret phenomenon, to which, in his opinion, corrosion of boiler and condenser tubes may be due. (Fourth Annual Lecture of the Institute of Metals Division before The American Institute of Mining and Metallurgi-

cal Engineers, New York meeting, February, 1925, by Carl Benedicks, Director of the Metallographic Institute of Stockholm, Sweden. *Transactions of the American Institute of Mining and Metallurgical Engineers*, no. 1449–E, *etA*)

ENGINEERING MATERIALS (See Power-Plant Engineering: Steam Pipes for Extra High Pressure and Temperature; Railroad Engineering: Rail Wear)

FUELS AND FIRING (See Power-Plant Engineering: Cost of Atomizing Fuel Oil)

HYDRAULICS (See also Testing and Measurements: Measurement of Pipe Flow by the Coördinate Method)

The Operation of Hydroelectric Systems with Auxiliary Steam Plants for Best Economy and Proper Governing

Briefly, the author recommends dividing the station load equally between those units in operation having duplicate efficiency curves and discusses methods of operation for best economy of a power station for a multiplicity of similar units giving duplicate performance curves. When dealing with hydroelectric systems in which there are plants operating under various heads and various-sized units, the performance curve of efficiency of each unit must be consulted to plan the operation for best economy.

Under some conditions it has been found a decided advantage to operate two or more plants on an intermittent basis. Actual application of the principle of operating two or more plants on the same river on an intermittent basis rather than on a continuous basis has recently resulted in as much as 10 per cent increase in kilowatt-hours on a given river flow. This operation consists primarily in absolute orders never to allow a unit to operate on the governor at gate openings between zero and about six-tenths. In other words, a unit on the line should be either shut down to zero gate opening or operated above six- or seven-tenths gate opening. Load conditions do not permit of this requirement unless deliberate steps are taken to meet it. Such steps consist of intermittently operating one plant above the load it would naturally take and an additional plant below the corresponding point. After a period, the length of which depends on the pondage available, the conditions are reversed in the two plants. Still further temporary shifting of load may be made between steam and water.

The setting of the governors in stations having duplicate units with duplicate efficiency curves should be such that they have the same inherent regulation. By inherent regulation the author means the percentage drop in speed from no load to full load when the load has been very slowly changed. All modern water-wheel governors are equipped with means for changing at will this inherent speed regulation. An inherent regulation of 2 per cent drop in speed from no load to full load is found sufficient to cause the governors to equally divide the load. In the system having units illustrated by efficiency curves of a different inherent regulation between, the governors should be made different. Those units having high part-load efficiency, giving a flat efficiency curve, should have small inherent regulation. Those units having lower part-load efficiency should have greater inherent regulation, so that under changes of load the greater percentage change of load will come on the more efficient units.

The author believes that the compensating devices used on hydraulic governors can advantageously be added to steam-turbine governors when operated as steam auxiliaries on hydroelectric plants, thereby obtaining a more uniform division of load changes than otherwise.

In practically all cases where steam turbines are operated as auxiliaries on hydroelectric systems, new and different problems must be met and solved in adjusting the governors to most satisfactory and efficiently meet these conditions.

The author does not lay down any hard and fast rules, nor, as he states, is it his intention to do so, the purpose of his paper being to point out and bring to the attention of engineers many of the problems to be solved in operating large systems, in the hope that discussion and study will bring about a better understanding and more complete solution of these problems. (Wm. M. White, Chief Engr., Hydraulic Dept., Allis-Chalmers Mfg. Co., Milwaukee, Wis., Mem. A.S.M.E., in a paper before the Third Annual Hydroelectric Conference, Philadelphia, 1925, 5 pp., 2 figs., *gp*)

Operation of Hydroelectric Units for Maximum Kilowatt-Hours

Only some of the features of this extensive and interesting paper can be abstracted. Among other things, the author discusses the subject of venting of reaction runners, i.e., admission of air to some portion of the runner or the passage surrounding it. For several years it has been the practice of the Allis-Chalmers Company to deliberately introduce vacuum breakers for the controlled venting of reaction runners to attain a condition where the runners ran in air. In this way one-tenth gate performance was secured in daytime simply by adding air pipes leading into the draft chest, it having been established that venting reaction runners at small gate openings gave greater output from the flow used. When synchronous-condenser operation of hydroelectric units came into general practice the application was carried still further and the ideal losses of the entire unit at zero gate greatly reduced by venting. Curves in the original article show the difference in power performance between the vented and unvented units. The venting advantage does not necessarily obtain with all types of reaction runners, nor is it advisable to use it under certain conditions of turbine setting wherein the elevations of turbine above tail level do not permit of the desired air admission.

As a general comment the author adds that synchronous-condenser operation of hydroelectric units is perfectly good practice, and as transmission lines become more and more extensive and voltage regulation more and more important, it is bound to be reported to an increasingly greater extent. This is particularly true as steam and hydraulic systems are more expensively interconnected, with the result that there is a greater excess of installed capacity of hydroelectric capacity over average stream flow. This means that there will be an increasingly greater number of idle machines available for power-factor correction purposes and while these machines may not be located ideally for absorbing wattless current, the mere fact of their existence without the extra cost involved in straight synchronous condensers will tend toward their use for this purpose.

As regards gate leakage, the opinion of the author is that it should be less than 1 per cent of the full discharge of the unit. Gate leakage is a function of certain factors enumerated in the original article, and the study of it brings up the question as to whether adjustable gates as understood today are not a very expensive luxury. If a simpler control that would add less cost to the turbine structure and at the same time permit of absolutely tight shutdown could be devised, it would probably better meet the real objective of our present-day design than the style of construction which we are bound to by habit and familiarity. Changing requirements of our systems should induce a very decided effort to depart from forms and structures the necessity for which may no longer exist, originating as they did under conditions of isolated-plant operation which required close regulation of individual machines. In other words, are not many of our costly turbine details traceable to general features of design which have little or no application to present-day requirements? More of this question is covered later in a section of the paper dealing with governors.

The subject of impulse wheels is discussed next, particularly in connection with the question of draft tubes. The conclusion to which the author arrives is that draft tubes as applied to impulse wheels for regaining flood height are not in themselves commercial. The windage effect probably has not been appreciated as to extent nor as to the possibility of elimination, and the two items together should be considered more fully. The author also considers the question of pitting in impulse-wheel buckets due to higher vacuum conditions and release of dissolved gases in such cases as, for example, when the jet issues from the nozzle into the vacuum space.

The part which apparently attracted most of the attention in the discussion was that of dealing with governors, and the author seems to believe that they are becoming rapidly obsolete.

When they are eliminated, and they will most certainly either be eliminated or so restricted in their operation as to become mere safety shutdown devices, the hydro unit will be greatly improved as a producer of kilowatt-hours.

The governors cost a lot of money. They reduce the kilowatt-hours that the turbine could otherwise generate if not saddled with their burden. They necessitate greater cost of turbine structure and in connection with flywheel effect usually increase the cost and decrease the efficiency of the generator. They most certainly reduce the continuity or reliability factor of operation of the plant, and correspondingly interfere with the quality of service and further reduce the kilowatt-hours. They greatly increase the possibility of accident and certainly do more than any other single cause to shorten the life of the turbine itself. They may be summarized as reducing the output and increasing the upkeep of the plant, thus bringing closer the two items, the difference between which means net income and profit to the owner.

It is not suggested that all control be eliminated; rather that it be so modified that it is a control rather than a governor, with thirty or sixty seconds operating time in place of two seconds. Governors regularly and repeatedly impose sudden strains on turbine structures of a magnitude averaging (if expressed in horsepower) an appreciable percentage of the full turbine capacity. A control should be based on about 1/10 to 1/30 of this governor capacity, the strains and wear correspondingly reduced in amount, and almost entirely reduced from a standpoint of repetition. It might still be a governor if so calling it would make one feel safer, but it would be free from the faults of our present practice and primarily much more conducive to the production of kilowatt-hours. It would be decidedly better for the average automatic station as it is freer from complications and troubles.

It may be of interest to know that in the last few years some 20-odd larger-capacity units, that is, running over 1000 hp. each, have been built without governors. Their operation to date has been everything that has been expected of them from a standpoint of kilowatt-hours produced. It should not be forgotten that the horsepower installed in this country at present in hydraulic turbines under governor control is far in excess of the momentary horsepower load variation, and as the systems increase with correspondingly greater diversity factor the actual load changes will undoubtedly further decrease. (F. Nagler, Hydraulic Engr., Allis-Chalmers Mfg. Co., Milwaukee, Wis., Mem. A.S.M.E., in a paper presented at the Third Hydro-Electric Conference at Philadelphia, Mar. 10, 1925, 8 pp., 6 figs., *gA*)

Interrelation of Operation and Design of Hydraulic Turbines

The economical selection of runner is the first subject taken up by the authors. It is usually governed partly by the head under which the unit must operate, and as a general guide in selecting the specific speed, and hence the type of runner. There was prepared some years ago by the leading turbine manufacturers a curve plotted between head and specific speed of the runner, known as an "experience curve." The authors believe the use of this curve is not a logical method for selecting specific speeds, and point out that if it were possible always to operate each turbine at its point of maximum efficiency, the type of runner would not be of any great import, for turbine runners have now been designed for a wide range of speeds, developing very nearly the same maximum efficiencies. Where it is necessary to operate a unit at part load the actual output obtained from a given discharge will differ quite widely for the different specific runner, and the authors show four runners drawn to the same scale (Fig. 2), each developing the same power under a given head but at speeds proportional to the specific speed indicated.

The authors therefore come to the conclusion that in considering any installation in which part-load operation is to be a factor, it becomes advisable to compare units of different speeds in order to select the most economical speed for the given conditions, and show a case where a lower-speed unit would be more economical to install and substantially more profitable to the power company in respect to yearly income.

The next section deals with load division among units in a station. Taking curves *A* and *B* in Fig. 3, showing the physical relation between output and discharge of two different units, the authors derive an equation which shows that for best economy the two units must be operated at points on their output curves having equal slopes or having equal values of the first derivative of output with respect to discharge. In this connection two cases are considered: namely,

1 Units having curves of output versus discharge, having at all points a form either convex or straight; and referred to as curves without points of inflection.

2 Units having curves of output versus discharge containing a reversal of curvature, and referred to as curves with points of inflection.

An analysis of these shows in the case of a two-unit plant that variations in total load are handled in the most economical manner

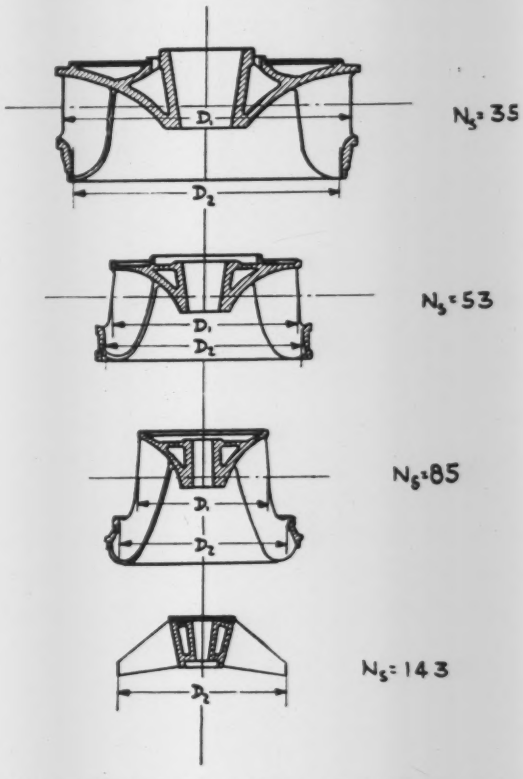

FIG. 2 RELATIVE DIMENSIONS OF RUNNERS OF DIFFERENT SPECIFIC SPEEDS

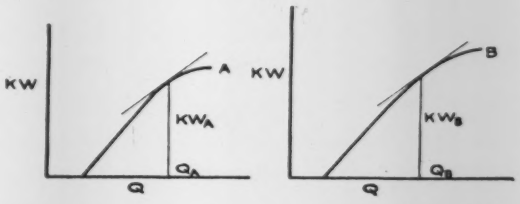

FIG. 3 TYPICAL RELATION BETWEEN OUTPUT AND DISCHARGE FOR TWO DIFFERENT UNITS

by installing at least one lower-speed unit in a plant where variations in stream flow occur. Next is considered a plant containing four 1500-hp. units under a head of 20 ft. where the flow during the year varies from that required by one unit to that required by all four units. The output-discharge curves with points of inflection are considered next. This is not suitable for abstracting.

The subject of pitting of turbine runners is then considered in connection with cavitation, and the authors agree with the report presented by Albion Davis at Atlantic City, May, 1924, and at Cleveland, February, 1925, to the Hydraulic Power Committee of the National Electric Light Association in which it is stated that the data seem definitely to establish the theory that serious pitting occurs on the surfaces of a runner only where there is a nearly complete vacuum.

In Mr. Davis' report the "total draft head" is taken as the static draft head plus the calculated velocity head in an axial direction

at the throat of the runner, and general deductions are drawn as to the allowable draft heads to avoid pitting. This method of comparison does not give the true vacuum due to velocity head, nor does it take any account of the local cavitation effect mentioned above.

To determine the vacuum due to velocity head, the absolute velocity at the throat of the runner must be calculated by first using the net area at this point (allowing for the area occupied by the runner vanes), and then correcting the velocity in an axial direction thus obtained for the angle of whirl of the water discharged at this point. The amount of the whirl component varies in runners of different design, usually increasing with the specific speed, and the actual amount of whirl for various specific speeds can best be determined by laboratory tests. It must also be borne in mind that the vacuum due to this velocity head is not equal to the full velocity head but only to that portion of the velocity head at the throat of the runner which is regained by the draft tube. Therefore correctly to determine this vacuum the absolute velocity head at the throat of the runner must be multiplied by the draft-tube efficiency. The actual values of efficiencies for different types of draft tubes can best be determined from laboratory tests.

The authors believe that draft head is a major factor in determining whether a turbine is likely to develop hydraulic corrosion or pitting, another important factor being form or design of turbine. Selecting the type of turbines suited for a given plant on the basis of an "experience curve" plotted between specific speed and head loss does not correctly serve the purpose of setting a limit on specific speed which will avoid danger of pitting, because it recognizes the effect of only one factor, head in relation to specific speed, and neglects a more important factor, draft head. A method for taking into account the local pressure reduction in the runner was developed by one of the authors and illustrated by applying it to the turbines of the propeller type. An equivalent method but different in form has been proposed in a paper by Dr. Dieter Thoma (Experimental Research in the Field of Water Power) presented at the First World Power Conference.

For purposes of closer computation, it will be of assistance when the data are available, as it is in all new designs, to separate the reduction of average pressure at the entrance to the draft tube from the local pressure reduction in the runner and to express these as separate terms. Each of these pressure reductions varies in direct proportion to the head on the runner; but the reduction in average pressure can be calculated with considerable definiteness, while the local reduction is dependent on so many complex or indeterminate factors that it cannot readily be found by any direct method of calculation. It is therefore proposed that the local pressure reduction be expressed by means of a cavitation coefficient equal to the ratio of local pressure reduction to head on turbine; and to gain some idea of its numerical value it has been calculated for all available installations from the reports of Mr. Albion Davis and the records of the I. P. Morris Department. The curves drawn by reference to points plotted with the cavitation coefficient and specific speed as coördinates can be used in much the same way as the earlier "experience curve" but to better advantage, as such curves are depended upon to find only one part of the total draft head, the remaining, and usually the greater, portion being directly calculated; and the method thus provided is free from the objections raised against the earlier method.

Two methods are available to gain some idea of the numerical values of the proposed cavitation coefficient k_c. Both methods were applied as shown by curves in the original article, and from these it would appear that there is a certain doubtful region where the possibility of pitting must be carefully considered. The lowermost curve may be considered to represent the danger line setting a limit below which one should not go usually in fixing the value of the cavitation coefficient k_c for a new installation. In presenting a discussion of the questions of cavitation and corrosion the purpose of the authors was to suggest a method of handling the problem rather than prescribe any precise numerical values in applying it.

The operating conditions and effect of draft-tube design and efficiency on pitting are next considered, and the authors come to the rather interesting conclusion that the only thing which has saved many an installation from serious corrosion in the past has been an inefficient draft tube. The conclusion is, of course, not that we must use inefficient draft tubes, but that due care must be taken to place the runner within the proper height above the tail-water surface. Recent improvements in draft tubes will call for more conservative values of static draft head than have been generally used in past practice. (Frank H. Rogers and Lewis F. Moody, Members A.S.M.E., respectively Chief Engr. and Consulting Engr. of the I. P. Morris Department, Wm. Cramp & Sons Ship and Engine Building Co., Philadelphia, in a paper presented at the Third Annual Hydro-Electric Conference, Mar. 10, 1925, Philadelphia, 18 pp., 25 figs., *t.A*)

INTERNAL-COMBUSTION ENGINEERING (See also Aeronautics: Aircraft Engines; Power-Plant Engineering: Cost of Atomizing Fuel Oil)

The Hunter Carburetor

WHILE the float chamber and slow-running jet (Fig. 4) are on normal lines, this carburetor has a sliding choke tube surrounding the jet and diffuser. This choke tube also acts as a throttle, for in its lowest position it closes the two ports which lead to the induction manifold; as the accelerator is depressed it raises the choke, opening the ports and allowing the mixture to pass to the engine.

Sliding centrally in the diffuser and jet is a tapered needle controlled by a Bowden wire and a small lever which is mounted upon

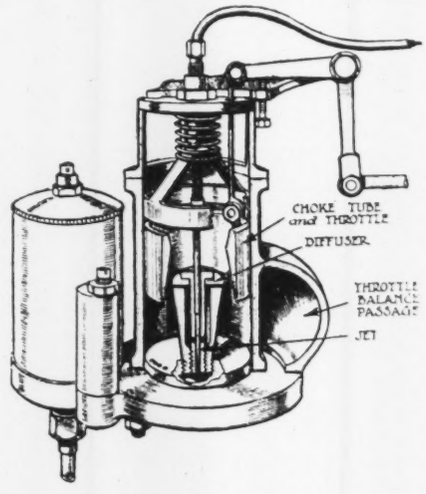

FIG. 4 SECTION OF THE HUNTER CARBURETOR SHOWING JET DIFFUSER, TAPERED NEEDLE, AND COMBINED CHOKE TUBE AND THROTTLE

the steering wheel. This allows the jet orifice to be varied according to the needs of the engine, and as the choke tube is raised beyond a certain position, it comes in contact with an annular slide attached to the needle control so that further movement of the choke tube automatically carries the needle with it, thus increasing the fuel supply through the jet for the full throttle opening.

Rough tests of the device are reported in the original article. (*The Autocar*, vol. 54, no. 1534, Mar. 13, 1925, p. 440, 2 figs., *d*)

An Automatically Lubricated Diesel Engine

DESCRIPTION of a new solid-injection type of Diesel engine brought out by Fairbanks, Morse & Co., of Chicago. Among other things it employs a mechanical lubricator driven from an eccentric on the crankshaft by means of a rocker arm and ratchet type of drive. Oil is forced to the cylinder piston and crankpin, and from these bearings the surplus finds its way to the lower crankcase, from which it is drained into a sump.

The main bearings are ring-oiling, with oil wells in the lower base. The governor and related parts are supplied by splash lubrication in the governor housing. Surplus oil which is pumped to the lubricator by the clean-oil sump pump overflows and is carried down over the eccentric and collects in the extension of the lower base that supports the injection pump and governor housing. The governor, dipping in the well thus formed, keeps

the pump cam, pump rocker, and rollers covered with oil. This well is interconnected with the main-bearing oil wells and is provided with an overflow that maintains a constant level of oil throughout the system.

In this engine the compression pressure has been raised to 500 lb. so that the engine can be started without the aid of a torch. An auxiliary combustion chamber is provided, into which the air rushes on the compression stroke and meets the atomized spray from the injection nozzle. The turbulence caused by this meeting of the air and fuel aids in preparing the fuel for complete combustion and also holds the charge in suspension. The fuel system consists of a single plunger pump for each cylinder and one auxiliary plunger pump which draws the fue from the auxiliary supply tank and then pumps it into the reservoir in which the injection pumps are submerged. It is possible to regulate the timing of the fuel injection by changing the angular position of the cam which operates the injection pumps. (*Power Plant Engineering*, vol. 29, no. 5, Mar. 1, 1925, pp. 310–312, 4 figs., *d*)

Exhaust-Gas Turbines and Superchargers

EXHAUST-GAS turbines have been applied in America to drive blowers which in their turn were used to supercharge engines as, for example, in the Moss supercharger designed by Sanford A. Moss (Mem. A.S.M.E.), but they have been used practically exclusively on airplanes to enable them to operate at a higher ceiling. In the article here abstracted is described an application of the same principle to a marine-engine drive, in particular, the equipment built by Brown-Boveri & Co. of Baden, Switzerland, and fitted on several German vessels, for example, the Hamburg South American liner *Monte Sarmiento*. Fig. 5 shows a section

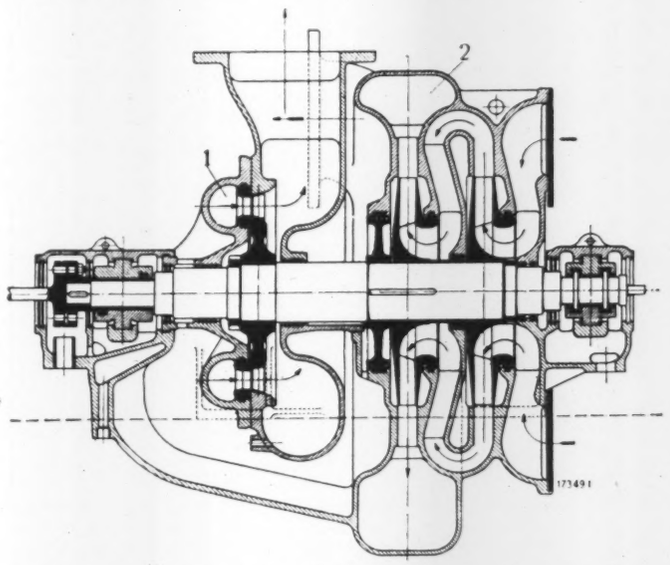

FIG. 5 SECTION THROUGH BLOWER AND EXHAUST-GAS TURBINE
(1, Exhaust-gas turbine; 2, Blower)

through the exhaust-gas turbine and blower. The machine would appear to be quite simple. A single disk mounted on the blower shaft but ordinarily overhung is all that there is inside the turbine casing. Owing to the relatively low exhaust temperatures of Diesel engines the materials usually employed for steam turbines can be used for the exhaust-gas turbines, especially as the pressures occurring are also as a rule very low.

From the blower shown in Fig. 5 about 3900 cu. ft. per min. of air can be delivered at a maximum pressure of about 7 lb. per sq. in., the blower running at a speed of 82 r.p.m. The nozzles of the turbine are so dimensioned that the back pressure during the exhaust stroke is kept as low as possible.

The purpose of the supercharging in marine oil engines is to increase the power of the engine beyond its sea-level rating. In practice, supercharging is limited not so much by the temperatures of the cylinder walls and valves as it is by the increase of combustion pressures which would impose excessively heavy stresses on the working parts. The highest supercharging pressure considered feasible for Diesel engines today is held by Brown-Boveri to be between 6 lb. and 7 lb. per sq. in. Theoretically the engine efficiency is improved by supercharging, but whether this takes place under the conditions of ordinary marine service has not yet been fully demonstrated.

There are two methods of supercharging. One is to keep the same compression ratio as the cylinder, the absolute final pressure being then raised to the same extent as the supercharging pressure. The other method is to use the same final compression pressure. The compression space in the cylinder must then be increased proportionately with the supercharging pressure, while the expansion ratio will become smaller. In the first method the increase of the main pressure is effected chiefly by the greater height of the indicator diagram, and in the second method by fattening of the indicator diagram. The original article gives curves showing how the output of the engine is increased by each of these two methods.

In supercharged engines the quantity of heat in the exhaust is greater because of the increase in the pressure and of the final pressure of expansion with a rise of exhaust back pressure.

It is on this result of the supercharging system that the use of the exhaust-gas turbine is based. The pressure needed for operating the turbine is not far different from that of the supercharging pressure; that is to say, a back pressure must be created on the exhaust about equal to the supercharging.

There is a choice between two systems of operation for the exhaust-gas turbine. One can use the variable-pressure system, which requires the exhaust gases to leave the cylinder at a high velocity. This would require the turbine to be installed close to the cylinders. The constant-pressure system seems to have greater advantage. In this system the exhaust gases are throttled sufficiently to give a back pressure, so that they feed to the turbine wheel at almost constant velocity. A comparison between the different methods available for driving supercharging blowers is given in the original article. It is not expected that the exhaust-gas turbine described here would be used to drive other auxiliary machinery. (*Motorship*, vol. 10, no. 3, March, 1925, pp. 203–205, 7 figs., *d*)

Sliding-Cylinder Double-Acting Two-Cycle Diesel Engines

DESCRIPTION of an engine made by the North British Diesel Engine Works, Ltd., as installed in the M.S. *Swanley*, a single-screw vessel built for Harris & Dixon by Barkley, Curle & Co., Ltd. The vessel is of the shelter-deck cargo type, 410 ft. in length by 55 ft. 3 in. breadth, with a draft of 25 ft. 4 in. and displacement of 12,560 tons at the load draft, and a speed at sea at this draft of $10^1/_2$ knots. The engine itself was described in MECHANICAL ENGINEERING, vol. 46, no. 6, June, 1924, p. 353. Some of the features are of particular interest.

The main connecting rods are of a different form from that usually met with in reciprocating engines. In this instance rigidity and not stress is the more important factor, and this is practically so in the case of the connecting-rod fork as any slight deflection of the fork arms will cause excessive displacement at the top and bearings. In order to obtain adequate rigidity the fork section has been made very deep. The combined tension and shear stress due to gas load is therefore very low, being somewhere in the vicinity of 2000 lb. per sq. in. for the down stroke and 1800 lb. per sq. in. for the up stroke, which enables the fork to be made of cast steel with safety. In the original article a series of stress curves for the connecting rod are given. The connecting-rod ratio is large, which makes the reaction on the guide slippers correspondingly low.

One of the unique features of the sliding-cylinder engine is that it will accommodate itself more readily to wear of the guide shoes than will any other type. With a uniform clearance between piston and cylinder of 20 thousandths, and a similar clearance between cylinder and cover, the guide shoe would have to wear 40 thousandths before the piston would begin to press heavily on the cylinder walls. In a fixed-cylinder engine of equal clearance the piston would press on the cylinder walls when the wear on the guide shoe exceeded 20 thousandths. It is claimed that the long connecting rod reduces the effect of the secondary unbalanced forces and couples in the engine.

The temperature of the cylinder liners is exceptionally low, as

shown by measurement by means of thermocouples with the engine on full load. From this it appears that the maximum temperature is 270 deg. fahr. with the temperature of water at the inlet of 102 deg. fahr. Similar readings for a typical four-cycle single-acting engine show a maximum temperature in the liner of 357 deg. fahr. The four-cycle unit has only one-third of the power output of the double-acting unit.

Several illustrations in the original article show the construction of the cylinder and the piston-cooling system.

The fuel valves as originally fitted in the engine were operated partly by the compression pressure in the cylinder and partly by the moving cylinder itself. This proved to be satisfactory for the most part, especially as regarded the top valves, but the bottom fuel valves were sluggish at times, and temporarily this arrangement was replaced by a cam-operated valve gear.

The starting piston valves and hand control gear are described in the original paper. The gear is such that the engine cannot be reversed until fuel and starting air have been cut off from all the cylinders. In this respect the gear is foolproof. Moreover, the levers, which may be operated either separately or together on fuel and starting air, also serve for reversing the engine and may not be moved separately during reversal. It is therefore unnecessary for the operator to change his grip when reversing.

A series of interesting balancing diagrams and curves of inertia forces per brake horsepower are given in the original article. From these it would appear that the torque is even and the reactionary balance good, i.e., the twisting effect on the ship's hull is more uniform than is generally found with oil engines.

The secondary forces and couples were taken into account when investigating the balance of this engine. In balancing reciprocating steam engines for merchant ships it has been customary to neglect secondary forces and couples, it being assumed apparently that the secondary effects were of such a high frequency as to be incapable of coinciding with the natural period or periods of vibration of the ship. Recent experiences with Diesel engines, however, have shown that an engine which is perfectly balanced with respect to the primary forces and couples may set up considerable vibration on board ship if the secondary unbalanced forces or couples are large.

The mechanical efficiency of the engine is discussed first by calculation and then determined by test.

Probably the most reliable results were those obtained by putting the top and bottom fuel-control handles at full power, recording the brake horsepower, and alternately withdrawing the top and bottom fuel handles and recording the brake horsepower developed by the top and bottom cylinders separately, the revolutions being kept constant.

A typical test of this sort gave the following results:

	B.hp.
With the top and bottom levers at "full power"	2005
With the top lever at "full power" and the bottom lever at "no fuel"	750
With the top lever at "no fuel" and the bottom lever at "full power"	758

From this, after accounting for horsepower lost in the compressor, scavenging pump, etc. a mechanical efficiency of approximately 80 per cent is derived. It is stated, however, that this figure will actually be a little high, but it is claimed that the mechanical efficiency cannot be below 75 to 76 per cent. From several fuel-consumption tests it would appear that the best consumption over extended tests was from 0.448 to 0.45 lb. per b.hp-hr. at full load with boiler fuel, but it is expected that this will be improved.

In a supplementary paper are given some data of trial runs in June, 1924, and the run from Cardiff to Port Said in July, 1924. From there the ship went down the Red Sea, where extremely hot weather was experienced, the sea temperature being 92 deg. fahr. The high temperatures had no effect on the working of the engine except that the temperature of the scavenge and injection air rose appreciably. The *Swanley* proceeded to Calcutta, and after several other trips reached Kiel at the end of October, 1924.

Toward the end of the homeward voyage a slight mishap occurred to two of the top end-bearing caps, owing to a partial failure of the forced lubrication system to these bearings. This failure of pressure oil was partly due to a slack main-bearing cover causing a loss of pressure in the forced-lubrication system, and partly to the presence of emulsion in the lubricating oil. A quantity of salt water had found its way into the crankpits, on the outward voyage owing to two of the safety disks on the air-compressor jacket bursting.

The top end bearings referred to ran hot for a while, but cooled down again when the forced-lubrication pressure was increased.

At Kiel the bearings were examined and found to be scored. This was rectified by the ship's engineers while cargo was being discharged at Kiel, and gave no trouble during the subsequent voyage to this country.

Since the return of the ship a number of alterations have been made, the principal alteration in the main engine being the elimination of the flexible cooling pipes for the cylinders. (J. C. M. Maclagan in *Transactions of the Institute of Marine Engineers*, vol. 36, Feb., 1925, original paper, pp. 665–746, numerous tables and illustrations, discussion, pp. 746–758, *dA*)

LUBRICATION

The Behavior of Lubricating Oils under Oxidizing Tests

ALTERATION in the composition of oil invariably leads to the formation of asphaltic bodies, due to the action of the air and the high temperature to which the oil is submitted in internal-combustion engines. When in this partially decomposed condition the viscosity in the cold state is invariably much greater than that of the oil initially. These alterations cause a series of troubles, among others being loss in efficiency of the engine due to friction. Experience shows that all oils on the market begin at some time or other to form asphaltenes, and the question before the author was to secure the chemical and physical data necessary to determine the behavior of a lubricant in this respect.

Among other things, in the course of the tests the decomposition of the oils was investigated microscopically in the belief that sludging would give some clue to the differences in the two oils and in view of the fact that sludging renders insoluble the asphaltenes produced. The results of this are shown in a series of photographs in the original article, but the author does not claim to have definitely determined what the products of decomposition are.

Among the tests there reported it is said that oil used in a certain car engine showed after a run of 500 miles the following analysis: Oil, 55.26 per cent; asphaltene, 8.70 per cent; and carbenes (or matter insoluble carbon tetrachloride), 36.0 per cent, the carbenes representing here a product close upon the heels of elemental carbon.

The conclusion to which the author comes is that oil which can be maintained the greatest length of time at elevated temperatures without showing signs of decomposition is the best suited for use in high-speed engines.

In the course of the discussion of the paper, cleaning of oil by centrifuging was mentioned. In his closure the author submitted the view that centrifuging, while in all probability removing suspended and precipitated matters, would not remove those asphaltenes that existed in the colloidal condition. Since, however, it would appear that asphaltenes in such a condition would be of direct use in increasing the efficiency of the lubricant, it was quite likely that judicious centrifuging might be of some help. (J. B. Hoblyn in *Journal of the Institution of Petroleum Technologists*, vol. 11, no. 48, Feb., 1925, original paper pp. 1–13 and discussion pp. 13–35, illustrated, *eg*)

MARINE ENGINEERING (See Internal-Combustion Engines: Sliding-Cylinder Double-Acting Two-Cycle Diesel Engine)

MECHANICS

The Michell Crankless Engine

NOTES on the dynamic balance of this engine. One of its interesting features is the perfect balance which can be obtained by a proper adjustment of the mass of the swash plate or "slant" in relation to the masses of the reciprocating units.

Its motion is simple harmonic, and the troublesome problem of

balancing the secondary forces and torques, as in the crank and connecting-rod mechanism, does not exist.

The inertia forces set up by the reciprocating masses produce couples in the frame which have a resultant whose axis continually coincides with the minor axis of the elliptic slant. This axis, which in a vertical engine always remains in a horizontal plane, is also the axis of the resultant centrifugal couple due to rotation of the slant.

The centrifugal couple and the resultant couple produced by the inertia forces of the reciprocating masses are opposed in sense, and consequently, with a suitable adjustment of the mass of the swash plate, a perfect balance may be obtained.

From this the author proceeds to a mathematical discussion of the proper relation between the mass of the plate and that of the reciprocating units. He finds that the inertia forces due to the reciprocating units set up a resultant couple of a certain magnitude and the axis of the couple corresponds with the minor axis of the swash plate.

With the given number of lines of reciprocating symmetrically arranged about the axis of the rotating shaft, perfect balance can be obtained when the number of lines of reciprocation is greater than two. Balance of torque is possible for a two-line engine in which the angular interval between the lines is 90 deg., but the forces in such an engine remain unbalanced. (E. C. Moyle in *The Automobile Engineer*, vol. 15, no. 199, Feb., 1925, pp. 41–43, 3 figs., *tm*)

METALLURGY (See Corrosion: Corrosion of Boiler and Condenser Tubes)

POWER-PLANT ENGINEERING (See Corrosion: Corrosion of Boiler and Condenser Tubes)

Cost of Atomizing Fuel Oil

A COMPARISON of the cost of atomizing fuel oil with five types of apparatus, namely, (1) mechanical atomizing, (2) steam atomizing, and (3) air atomizing with pressure of 8 oz., 2 lb., and 80 lb., respectively. The data given cover equipment cost, fixed charges and maintenance, and cost of steam, air operation, and labor. From a table in the original article it would appear that the cost of mechanically atomizing fuel oil per 1000 gal. is $1.58 ($4.15), and of steam atomizing, $3.21 ($4.68). Air-atomizing costs are as follows: With 8 oz. pressure, $1.89 ($3.36); with 2 lb. pressure, $3.26 ($4.73); and with 80 lb. pressure, $6.53 ($8.00). The table gives detailed figures for installations of 150 hp., 300 hp., 900 hp., 1950 hp., and 4500 hp. The figures cited above are for the latter unit and (in parentheses) for the 150-hp. plant. (Chaplin Tyler, of the editorial staff of *Chemical and Metallurgical Engineering*, in *Chemical and Metallurgical Engineering*, vol. 32, no. 8, Feb. 23, 1925, pp. 323, 1 fig., *p*)

Steam Pipes for Extra High Pressure and Temperature

A PAPER based on deductions drawn from actual experience of pipes working under a maximum temperature of 750 deg. fahr. with the steam pressure at 400 lb. per sq. in. under ordinary conditions. In the opinion of the author such temperatures and pressures do not produce any new difficulties, but they accentuate all the old ones and make it more than ever evident that the design of steam piping is as much a matter for expert knowledge as that of any other item in a power station. However, pipes are now so reliable and the chance of entire breakdown so small that it is quite unnecessary to duplicate them. The diameters of the pipe should be kept small by a high-velocity flow, which is obtainable by a drop in pressure of, say, as much as 10 lb.

Expansion is the ultimate cause for most of the trouble in pipe lines. It occurs either as a result of variations from dead cold to the highest steam temperatures, or may be due to extraneous causes.

The author recommends the use of wide bends in the run of the pipes, or as the next best thing, expansion bends of the lyre type. To save space, bends made from corrugated pipes are now being used, as for the same dimensions they give five times the amount of movements for expansion. Also corrugated pipes are stronger than plain pipes, because the process of manufacturing thickens the crown and the base of the corrugations, and they can only be made from the best quality of tubes.

The author recommends making the pipes as long as possible, 30 to 35 ft., to reduce the number of joints. The elimination of joints by welding up pipes in long lengths on the site is very attractive, but there has not yet been sufficient experience to justify recommending its adoption for the highest pressures. Some practical recommendations as to the making of joints and welding flanges to pipes are given. (J. Arthur Aiton in a paper before the Institution of Engineers and Shipbuilders in Scotland, abstracted through *The Iron and Coal Trades Review*, vol. 110, no. 2974, Feb. 27, 1925, p. 347, *p*)

Exposing Water-Tube Surfaces to Flame

AN INVESTIGATION on this subject was conducted by Michel Sohm, chief engineer of the Mines de Bruay, France. This concern erected the first complete boiler plant in Europe to be fired with pulverized coal. Their tests were conducted to determine the effect of boiler-tube surfaces directly exposed to the radiant heat of fire, and also the rate of combustion per cubic foot of furnace per hour and the temperature variation of flame and gas in the combustion chamber and in each pass of boiler from burner to damper.

From these tests it would appear that the transfer of heat by radiation to the boiler surfaces controls the temperature of gases. The quantity of combustible that can be burned without slagging in tubes is proportional to the amount of tube furnace exposed to the fire and is influenced by temperature at which the ash will become liquid. (J. Gould Coutant, Mem. A.S.M.E., in *Combustion*, vol. 12, no. 3, March, 1925, pp. 191–192, 2 figs., *e*)

Evaporative Tests at River Rouge

RESULTS of five tests conducted at the River Rouge plant of the Ford Motor Company on boiler No. 1, one of eight 2647-hp. Ladd water-tube boilers using pulverized coal. The tests were made for sustained boiler loads up to 285 per cent of normal rating and were run to determine the combined efficiency of the furnace, boiler, and superheater when pulverized coal was the fuel. The original article describes how the tests were made and gives the data and results obtained. The efficiencies obtained ranged from 77.8 to as high as 82.2 per cent, and a claim is made in the original article that the data from which these tests were computed are of such accuracy that the efficiencies reported are probably correct to within plus or minus 1 per cent. The actual evaporation per pound of fuel as fired varied from 8.22 to 8.74 lb., the lower figures both for efficiency and for actual evaporation belonging to the lower per cent of boiler rating (150.4) and the higher figures to the higher per cent of boiler rating (285.9).

Because of the readiness of the ash to fuse it was found difficult to operate the furnace of boiler No. 1 with low excess air. No provisions exist for cooling the solid walls, which in places are more than 2 ft. thick, nor are there any water screens in the furnaces. At ratings below 200 per cent the large cross-section of the large furnace caused the gas velocities through the furnace to be low so that the furnace walls were, in a manner, subjected to soaking heats. The heat-storage capacity of the thick walls was large, and because of their thickness radiation from their outer surfaces did not help much in cooling them. Consequently when once the ash on the walls became fluid and dripping was imminent, only bold changes in the furnace draft, that is, bold increases of excess air, were effective in preventing or stopping the dripping. Attempts to run with high CO_2 resulted in serious dripping of the walls, and in test No. 1 the slag for a short period became fluid enough to flow out through the ashpit doors. After freezing over the doors this slag could be removed from without, and it was not necessary to shut down the test.

During test No. 2 the arches, which were made up of large blocks, showed signs of cracking and spalling. The sharp corners of the nose tile were especially subject to cracking. During test No. 3, after about 30 hr. of operation the spalling of the east arch had progressed so far that part of a flat arch tile just forward of the large steel girder from which the arch is hung and just north of the center of the arch fell into the furnace and exposed the girder to radiation

from the furnace. Two hours of exposure caused part of the steel girder mentioned to assume a cherry-red heat. To prevent any possible damage to this girder the test was closed after it had progressed 32 hr. (*Power Plant Engineering*, vol. 29, no. 5, Mar. 1, 1925, pp. 275–278, 3 figs., *e*)

Steam Generation under Critical Conditions

The paper here abstracted endeavors to give the essential principles of the Benson process of generating steam under critical conditions and its utilization at very high pressures and temperatures of superheat. Brief particulars of the process were given in Mechanical Engineering, vol. 46, no. 5, May, 1924, p. 288.

The first plant erected consisted essentially of a very long coil of steel tubing 1/4 in. thick and 3/4 in. bore, arranged vertically between an inner and outer casing of refractory material. The coils were about 8 ft. high, and at the top of these coils which formed the actual generator were the subsidiary coils for superheating; the whole arrangement was approximately 17 ft. in height and 7 ft. in diameter and was heated from the top by means of an oil blast. Distilled water was passed in continuously at the bottom from a gear-driven force pump operating at 3200 lb. pressure per sq. in. The water traveled upward through the coil and was gradually heated, until finally, within about 10 per cent of the discharge end, it reached 706 deg. fahr., the volume being then about three times that of water at 60 deg. fahr. The pressure was of course all the time at 3200 lb. because of the pump, and the whole mass of the water was then quietly converted into steam at the same volume without ebullition and the absorption of any latent heat. In the remaining 10 per cent of the coil the steam was slightly superheated to about 720 deg. fahr. The steam was then discharged through a special reducing valve and the pressure lowered, the temperature falling to about 620 deg. fahr. and the steam going to a superheater so that the final pressure of the steam was 1500 lb. per sq. in. and the temperature approximately 790 deg. fahr., i.e., about 195 deg. fahr. of superheat at the given pressure.

While the advantages of very high steam pressures have been well known for a long time, their extended use has been prevented mainly by constructional troubles, chiefly because of ebullition caused by latent-heat absorption, the main difficulty being that of building the boiler, this difficulty being due to latent heat and the sudden and violent conversion of a small volume of liquid water into a very large volume of steam. Benson, however, has solved the problem by going right up to the critical conditions of pressure and temperature and converting water into steam at the same volume, without the absorption of any latent heat.

The author points out that even at pressures extremely high but below those used by Benson a difficult situation exists, as, e.g., at 2000 lb. gage pressure the latent heat is still approximately 480 B.t.u., just over half that at atmospheric pressure, which is sufficient because of ebullition to make the coil or tube boiler an impossible proposition.

The original design of the proposed experimental layout for Rugby, England, was reproduced in P. W. Swain's article in *Power*, May 22 and 29, 1924, in which the first description of the Benson generator was given. The purpose of the Rugby plant was to find out whether steam could be generated on a large scale at the critical conditions. To operate commercially with this steam a turbine is required to work at 20,000 to 25,000 r.p.m. with steam at 1500 lb. per sq. in. and, say, 850 deg. fahr. temperature, and a higher pressure may possibly be employed. There are no special engineering difficulties in the way of constructing such a turbine today. In the tests at Rugby on Feb. 18, 1924, the installation was operated for 6 hr. at the critical conditions, water at the rate of 8000 lb. per hr. at 3200 lb. pressure per sq. in. being passed through. It is claimed that the Benson plant at 1500 lb. and 850 deg. superheat will give an efficiency of about 30 to 32 1/2 per cent, and that a higher efficiency can be obtained by operating at 2000 lb. or over with several stages of reheating. The steam-generation efficiency is claimed to be very high and may easily reach 95 per cent, because of the intense localized flame used with little excess of air over the theoretical, almost negligible, radiation losses from the casing and the low temperature of the final exit gases after passing the heater.

As regards the auxiliary power required for pumping the feed-water and operating the oil blast (gas or pulverized fuel would, however, do equally well), the figure corresponds to approximately 6 per cent of the steam generated. The danger of the high pressure can be regarded as negligible, because of the small water content. (The rate of insurance is no more than for the average steam plant.) It is claimed that the capital cost of the complete installation will be considerably less than the present ordinary high-pressure steam plant. (David Brownlie, Mem. A.S.M.E., in a paper read at the joint meeting of the Institution of Chemical Engineers and the Chemical Engineering Group of the Society of Chemical Industry, Feb. 11, 1925; abstracted through *Chemistry and Industry*, vol. 44, no. 9, Feb. 27, 1925, pp. 213–219, 2 figs., *d*)

The Brunler Subaqueous-Combustion Boiler

All steam-boiler constructions now in use (with the exception of the electrically heated boiler) are based on the idea of producing heat on one side of a good conductor and endeavoring to transmit as much of this heat as possible through the partition to the steam-generating liquid. Of course large heat losses are unavoidable in this process. From this point of view the boiler described by Oscar Brunler in a paper before the recent meeting of the Institution of Chemical Engineers and the Chemical Engineering Group in London (February 11, 1925) is a wide departure in design.

The Brunler boiler was originally worked out by Oscar Brunler, Sr., the father of the author of the paper, many years ago, and was described in Mechanical Engineering, vol. 36, 1914, p. 053–055.

The fuel (crude oil, etc.) and the air which is necessary for combustion are supplied to the burner under a pressure which barely exceeds the pressure of the steam. Before starting, the connection valve is closed, and the water level in the generator must not be above the lower mouth of the burner. The cover of the ignition lamp is removed after heating the fireclay lining of the ignition lamp, and the oil and air ignite on the fireclay lining. The cover is then pulled down again, and the flame of the ignition lamp makes its way to the burner. After a few minutes the main burner is hot enough, and the main regulating valve is opened and the flame burns in the generator. The connecting valve to the water reservoir is now opened and the water in the generator rises up to the middle of the burner. The flame which is burning quietly in the water can be observed through the peepholes in the generator. By means of the superheater, which consists of a small burner similar to the ignition lamp, its flame burning in the steam reservoir, the steam can be superheated to any required degree. The size of the flame and consequently the quantity of steam is regulated by means of the regulating valve; at the same time the ratio of oil and air is kept constant. By turning a wheel the size of the flame can be regulated without changing the air-fuel ratio. Therefore it is not possible that the combustion can be altered through mistakes of the stoker. The temperature in the center of the flame is approximately 1800 deg. cent. This temperature diminishes to the periphery of the flame, so that between the center of the flame and the periphery a rapid fall of temperature takes place. Since a permanent stream of burning gas has to pass through this fall of temperature, it is evident that the last traces of carbon monoxide must be converted into carbonic acid. In effecting the combustion in such a way the possibility is insured of burning the fuel more completely than in the open air. The combustion under pressure brings the molecules of the fuel into better contact with the oxygen, therefore under pressure and in water the most complete combustion can be obtained.

Whether the boiler can be applied for power generation economically is still a question. It is not suitable for use with large turbines, because of the excessive amount of non-condensable gases mixed with the steam, which would make the operation of condensers difficult and uneconomical. Where, however, the purpose is concentration of liquids or chemical solutions, the Brunler system may find application. The original paper gives cost calculations which would indicate that it can be employed quite economically for certain purposes.

It is stated by the author that in practice in certain cases there was obtained an efficiency of more than 100 per cent. This would indicate that there was either an error in the determination of the calorific value or in calculations, which is not likely, however, because it is claimed that the experiments were carried out with great

care. If so, there must be some kind of latent energy that is set free during combustion which is not utilized in ordinary boilers.

In an earlier publication (*Zeitschrift für Dampfkessel und Maschinenbetrieb*, Jan. 9, 1914) it was stated that one pound of tar oil produced the evaporation of 20 to 21 lb. of water, and in some cases as high as 24 lb. of water from a solution of tungstic acid, where the theoretically possible evaporation is only 14 lb. This was ascribed to the chemical action of ultra-violet rays produced in the flame, which in an ordinary flame would be kept back from the water by the screening action of the metal wall. Fig. 6 shows the Brunler

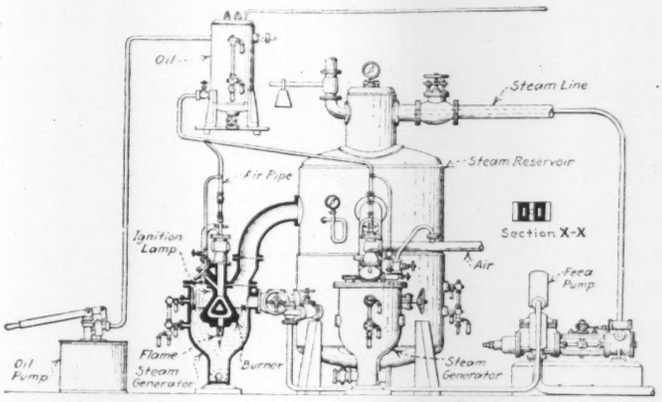

FIG. 6 ELEVATION OF THE BRUNLER SUBAQUEOUS-COMBUSTION BOILER INSTALLATION SHOWING ONE STEAM GENERATOR IN CROSS-SECTION

plant diagrammatically. (*The Chemical Age*, vol. 12, no. 296, Feb. 14, 1925, pp. 150–151, and *Power*, vol. 61, no. 10, March 10, pp. 379–380, 2 figs., *d*)

RAILROAD ENGINEERING

Turbo-Generators for Train Control

PRIOR to the advent of train control, signal engineers had little or no reason to concern themselves with any of the equipment which goes on the locomotive. It is quite natural for one now to direct his attention to the turbo-generator furnishing power for locomotive lighting and which is rightfully regarded as the proper course of current supply for train control. The locomotive turbo-generator is called upon to operate under all kinds of weather conditions and must successfully withstand the severe shocks imparted to it from the locomotive. It has constant speed and voltage over a wide range of steam pressures. The speed can be kept within two per cent of the rated speed from no load to full load. The loading in lamps ordinarily found on the locomotive is about 375 to 425 watts. The cab load is with few or no exceptions connected directly across the generator terminals.

It is commonly supposed that the headlighting turbo-generator is run only at night when the headlight is required. Such is not the case, for with the increased size of locomotives and the multiplicity of gages, etc. in the cab the engineman finds it necessary today to have the generator running to furnish light in the cab, even in the daytime. An average of the time that the headlight turbo-generator is in operation will exceed 75 per cent of the time the locomotive is in operation. The utilization of the turbo-generator the extra part of the time will not add appreciably to the cost of operation or maintenance.

In addition to close voltage control there is another requirement being imposed by the continuous induction types of train control. That is, that the voltage wave shall be entirely free from any pulsation or alterations, since any such irregularities will result in loading up the vacuum tubes used to amplify the currents picked up by induction from the "track" and "loop" circuits. The major part of these irregularities experienced from the turbo-generator in conjunction with the continuous induction devices has not been due to inherent defects in the turbo-generator equipment, but rather to disorders which creep in as a result of operating conditions such as excessive vibration, poor brush fits or surfacing, worn bearings, etc. Designs of equipment are under way, however, and will be soon available which will not only be free from all such irregularities but of such a nature as to insure against any changes due to operating conditions and common maintenance practices.

Years of development and progress with well-established maintenance forces on every railroad operating staff make the turbo-generator a unit which should assist and never retard the most progressive and interesting art that has ever been made part of railroad practice—automatic train control. (Paper by J. J. Kennedy, Elec. Engr. of the Pyle National Co., before the Annual Convention of the Signal Section of the American Railway Association, Chicago, March 12 and 13, 1925; abstracted through *Railway Age*, vol. 78, no. 16, Mar. 21, 1925, pp. 789–790, *g*)

Gasoline-Driven Cars with Hydraulic Transmission on Swiss Federal Railroads

Two types of such cars have been installed on Swiss railroads: one with gasoline motors of 100 hp. and the other with Diesel-electric drive of 250 hp. The present article deals in particular with the gasoline-driven cars, of which again there are two types: one with the usual hand-operated gear drive, and the other with a hydraulic-operated drive. This latter has been developed by the Swiss Locomotive and Engine Works in Winterthur and is different from what is known as hydraulic transmission in this country. The engine power is delivered by the drive from the crankshaft and is transmitted to the driving axle through a set of spur gears, there being facilities for obtaining four speeds. With an engine speed of 1000 r.p.m. this gives road speeds of 10, 17, 30, and 50 km. (6.2, 10.5, 18.6 and 31 miles) per hour. All the gear wheels of the change drive are in mesh all the time. The wheels of the secondary shaft of the change drive are equipped on the inside with metal friction clutches operated by oil pressure. This latter is controlled by the driver, who can cut in and out any of these clutches. When the clutch controlling one of the speeds is let in the clutch controlling the preceding speed is automatically released. From this it would appear that the transmission is really an ordinary gear transmission, but inside of the hand-operated gear shift is employed a system of hydraulically controlled engagements. No constructional details are shown in this article, but some of these were described in a preceding article, August 10, 1924, p. 86. (Dr. F. Cristen, Engr. of the Swiss Federal Railroads in *Schweizerische Bauzeitung*, vol. 85, no. 9, Feb. 28, 1925, pp. 115–117, 9 figs., *d*)

Wear of Rails

IN A RECENTLY published book Ch. Frémont, a well-known French metallurgist, takes up the subject of the wear of rails. The general impression is that the harder the steel the less the wear. Frémont shows, however, that this is not always so, and that the softer and apparently weaker rail may give better results. The usual method of measuring the strength is to divide the final breaking stress by the initial cross-section of the metal. Frémont claims that the proper way of measuring the strength of materials as applied to rails is to determine what he calls "final strength" in tension, which is the breaking stress divided by the rail section at the time of rupture, i.e., the section produced as a result of the reduction of area. He cites examples where an extra soft steel showing a conventional final strength of 37.7 kg. per sq. mm. (53,600 lb. per sq. in.) gave a final tensile strength as determined by him of 111.4 kg. per sq. mm. (157,800 lb. per sq. in.), while a semi-hard rail steel with a conventional breaking strength of 74 kg. per sq. mm. (105,200 lb. per sq. in.) gave a "final" breaking stress of 85 kg. per sq. mm. (120,800 lb. per sq. in.).

Frémont proceeds next to the consideration of causes that produce wear on rails. He dismisses the hypothesis proposed by Snellus in 1882 to the effect that wear on rails is produced by abrasion with the observation that it would be admissible provided it could be proved that the rolling of train wheels over the rail produces actual separation of particles of metals, which is not true except in certain unusual cases.

The hypothesis of J. E. Howard that wear of rails is due also to cold rolling is not accepted by Frémont, who points out that cold rolling would produce the principal deformation in the longitudinal direction of the rail, while actually the rail is deformed laterally.

According to Frémont, a rail is a beam supported along its length

at certain equidistant points. When the wheel load is applied to the rail it bends in a certain direction and bends back into its original shape when the wheel passes over one of the supports. Owing to these alternating bendings, the head and base of the rail alternately undergo vigorous compressions, of short duration and varying with the spacing of the supports and velocity of the movement, but on the average being of the order of $^1/_{20}$ to $^1/_{30}$ of a second from one flexure to another.

Tests carried out by Frémont indicate that had these stresses been of a *static* nature, they would be well within the limit of elasticity of a rail material made of soft steel. The stresses would have been static if the wheel rolling over the rail had a very slow speed. Actually, however, it does not; on the contrary, it runs at a very high speed, and the duration of the contact of the wheel with the point of the rail is extremely short, of the order of $^1/_{2500}$ of a second for a velocity of 72 km. (44.7 miles) per hr.

The violent and rapid contact produced by the horizontal displacement of the wheel over the rail is of the nature of a blow similar to one that would be produced if a weight such as a hammer fell on the rail vertically. The layer of steel at the surface of the rail, being suddenly compressed, does not have sufficient time to transmit the stress to the underlying layers and is constrained to absorb by itself very nearly the entire amount of the dynamic work that it has received. It is important, therefore, to bear in mind that the pressure produced at the point of contact of the wheel and rail is a *dynamic* action, with the velocity of impact increasing with the speed of the movement of the train. It was found whenever metal was subjected to hammering that there was a certain amount of inertia, which produced a compression of the layer immediately under the hammer and lying between the hammer and the layers beneath the one being hammered. As in hammering, the deformation takes place transversely to the longitudinal axis of the rail, because in this direction it encounters much less opposition to deformation than it would in the longitudinal direction. The conclusion to which the author comes, therefore, is that the normal wear of the rail is a result of an inertia phenomenon, and as a method of decreasing this wear it is suggested that a much softer metal be used than is done today. (Ch. Frémont in No. 69 of his series of *Etudes Experimentales de Technologie Industrielle*, abstracted through *Bulletin Technique de la Suisse Romande*, vol. 51, no. 5, Feb. 28, 1925, pp. 49–53, 8 figs., *et*)

Steam Motor Cars for a Porto Rican Railroad

DESCRIPTION of new units delivered by the Baldwin Locomotive Works for service on lines of the American Railroad of Porto Rico, which proved to be so economical in operation that a fare reduction was effected and three more units were ordered.

The cars were designed with sufficient power capacity to enable the handling of a trailer car. The cars themselves are of steel construction with a seating capacity of 46 persons and are electrically lighted. The engine compartment is separated from the passenger section by a fireproof partition.

A locomotive-type boiler with 262 sq. ft. of evaporative heating surface, 35 sq. ft. of superheating surface, and a grate area of 6.75 sq. ft. furnishes ample steam to the engines for all operating conditions which may be required, including that o occasionally handling a trailer car. A saddle tank of 400 gal. capacity located over the boiler contains the fuel-oil supply. The engine, which is of the two-cylinder simple type, is built into the drive truck as a unit. This truck has six wheels, four of which are driving wheels. The cylinders are 9 in. bore by 12 in. stroke and are of the piston-valve type, steam distribution being effected by means of a Walschaerts valve gear. The entire stock is arranged to swivel on a center plate and is equipped with roller side bearings similar to those used on a passenger-car truck. The steam supply line is fitted with flexible joints and the exhaust line is equipped with joints of the ball and slip type. The flexible joints in both these lines are packed with asbestos. A speed indicator and recorder is attached by means of a driving-wheel mechanism, and a dial located in the engine compartment indicates the running speed together with the air-brake main reservoir pressure. This speed indicator and recorder provides a graphic record as well as visual indications. The opposite end of the motor car is supported on a four-wheel passenger-car truck. Both the driving and the rear trucks are equipped with Westinghouse air brakes. Standard M.C.B. couplers and iron pilots are provided on both ends of the car. (*Railway Age*, vol. 78, no. 16, March 21, 1925, pp. 793–794, illustrated, *d*)

REFRIGERATION

Recent Developments in Refrigeration Research in England

AN ARTICLE based on the work of the Engineering Committee of the Food Investigation Board in England and dealing with a number of separate investigations.

One of the subjects investigated was convection currents and their bearing on the question of the best density of packing. From the investigation it would appear that the function of such insulating materials as granulated cork, charcoal, or slag wool when properly applied is to subdivide the air space into such minute cells that convection, though not entirely prevented, is greatly reduced and ceases to be important.

Loosely packed fibrous materials and ordinary granular materials do not entirely suppress convection, consequently the relation between the thermal conductivity and the density of packing is a function of the dimensions of the test specimen.

As a result of the investigations it was found that:

1 For densities of packing greater than 13 lb. per cu. ft. all three sets of apparatus seem to give the same relation between density and conductivity.

2 The relation referred to is approximately a straight line, which, if produced to cut the vertical axis, points to a conductivity of the order of 0.00008 corresponding to zero density of packing.

3 For densities less than 13 lb. per cu. ft. the 12-in. apparatus follows the above-mentioned line, except for a slight upward tendency at the lower end, which indicates the probability of a minimum of conductivity below 5 lb. per cu. ft.

4 The 20-in. apparatus shows a minimum of conductivity at 8 lb. or 9 lb. per cu. ft., with a small difference in the values according to whether the layer under test is vertical or horizontal.

5 The 60-in. apparatus in all three positions gives higher minima of conductivity than the 20-in. apparatus, the minimum for the vertical position being considerably higher than that for the horizontal positions, which do not differ greatly among themselves.

The following recommendations were also made as to the operation of condensers in refrigeration: (1) To purge condensers from the bottom instead of the top, and to make all connections to and from condensers, free from traps; (2) To equip the condenser with some means whereby the non-condensable gases can be kept from lodging in the condensing zone; (3) When the liquid leaving the condensers is found to be sub-cooled, to take this as an indication that the condenser contains a non-condensable gas; (4) To keep a daily record of the power required to drive the ammonia compressor, separate from all other power used. (Dr. Ezer Griffiths in *Proceedings of The British Cold Storage and Ice Association*, vol. 21, no. 1, 1924–1925, pp. 37–56, *e*)

STEAM ENGINEERING

Steam Table for Low Pressures

IN CONNECTION with the work in the evaporator laboratory of the Evaporator Experiment Station at Ann Arbor, Mich., of which the author is director, tables were compiled to cover the range from 90 to 1100 mm. mercury absolute pressure, corresponding to a temperature range from 49.5 to 110.7 deg. cent. (121.1 to 230.9 deg. fahr.). The latent heat in kilogram-calories is given in the table under the corresponding temperature. (W. L. Badger in *Chemical and Metallurgical Engineering*, vol. 32, no. 5, Feb. 2, 1925, p. 197, 1 table, *t*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Engineering and Industrial Standardization

Pan-American Standardization Conference

THE organization of some form of a national standardizing body in each of the American republics was one of the formal proposals of the first official Pan-American Conference on standardization held from December 23 last to January 6 in Lima, Peru, according to a report to the American Engineering Standards Committee by Albert W. Whitney, who served as chairman of the U. S. Government delegation.

Mr. Whitney reported that standardization is not yet developed in any of the Latin-American countries on an organized basis, and it was the belief of the conference that the subject would play an important part in the future of these countries, first, in making more efficient and expediting their industrial organization, second, in simplifying and clarifying international trade, and third, and most important, the development of better methods of producing and marketing their products.

The recommendations of the conference, which was an official body representing thirteen countries, were made to the Inter-American High Commission and to the twenty-one American republics represented on it. Provision was made for holding the next conference, either two or three years hence, in the United States.

The following is an abstract of certain recommendations made by the conference.

First: It is recommended that the American countries enter into a convention containing the following essential points:

(*a*) An agreement to provide for continuous study and to secure the establishment of common standards and nomenclature, uniform quality bases, simplified classifications, and standard specifications for raw materials and industrial products.

(*b*) To carry out this agreement the several countries will bind themselves to establish within their respective jurisdictions, one or more organizations, which may be under the administration of the government or under private administration, or under an administration composed of both governmental and private elements, as may seem best to each of the states signatories of the convention.

(*c*) The organization of organizations which may be established in each country will constitute national centers for the investigation and study of theories relating to this subject; they will establish methods of test, will be charged with the custody of accepted standards, and will either serve as intermediary itself or will maintain a close contact with the national organization serving as intermediary for the international exchange of ideas and experiences in this field.

(*d*) The aforesaid organization, whether governmental, private, or mixed, should comply with certain prescriptions and regulations, including the following:

1 The maintenance of an adequate personnel
2 Measures to obtain adequate coöperation and to consult representatives of all interests and enterprises in their country, in the establishment of national standards
3 The obligations of publishing or having published the methods of procedure followed, the results obtained, and any other information which may be of interest.

(*e*) In order to maintain Inter-American communication in this subject and to secure the establishment of Inter-American Standards, the Inter-American High Commission, through the National Section of each country and the Central Executive Council, is charged with the receiving and distributing of information relating to the work done in each country; the Commission will direct or perform such studies as it may believe advisable, will draw up proposals, and will take all necessary measures within its sphere of action to promote the establishment of Inter-American Standards.

(*f*) The nations will bind themselves to increase the technical and other personnel of their respective sections of the Inter-American High Commission, if this be necessary, in order that no economic obstacles may be encountered in this work.

Second: It is recommended that the Inter-American High Commission study and draft, the convention referred to in the previous resolution, redacting it in such form as may be most suitable to realize speedily the aims of these resolutions.

Third: Until the foregoing convention has been drafted and signed by the nations of America, it is recommended that the Inter-American High Commission work for the adoption within each country of measures in accordance with the proposed convention.

Fourth: It is recommended that the Inter-American High Commission undertake the gradual compilation of a vocabulary or list of standard scientific terms, in Spanish, Portuguese, English and French, and that all nations make such arrangements as may be necessary to coöperate in this work.

Fifth: In connection with the uniformity of weights and measures it is recommended:

(*a*) That this subject be entrusted to a committee for study and report at the next conference. The Inter-American High Commission is charged with the appointment of this Commission, upon which all American countries should be necessarily represented.

(*b*) That the units of weights and measures used in the various countries tend toward the metric system and that the new specifications, and any modifications which may be made in those now in existence, be expressed in C.G.S. units.

(*c*) That in catalogs and industrial and technical literature, where weights and measures of other systems are used, these should be accompanied so far as possible by their equivalents in the metric decimal system.

Sixth: It is recommended that there be held a Second Pan-American Conference on the Uniformity of Specifications within a period of not more than three years, in the United States of America, and in the city and at the time which the Inter-American High Commission may designate.

Recommended Practice for the Painting of Foundry Patterns

ACCORDING to a Bulletin issued to sustaining members of the A.E.S.C., a Joint Committee on Pattern Standardization, consisting of representatives from the following organizations, has brought in recommendations for standard practice for painting of patterns:

American Foundrymen's Association
American Institute of Mining and Metallurgical Engineers
American Malleable Castings Association
American Society for Testing Materials
Foundry Equipment Manufacturers' Association
National Association of Pattern Manufacturers
National Association of Purchasing Agents
Steel Founders' Society

The Committee's recommended practice, adopted in October, 1924, is as follows:

Surfaces to be left unfinished are to be painted black. Surfaces to be machined are to be painted red. Seats of and for loose pieces are to be red stripes on a yellow background. Core prints and seats for loose core prints are to be painted yellow. Stop-offs are to be indicated by diagonal black stripes on a yellow base.

The chairman of the Committee is Mr. E. S. Carman of the Osborn Manufacturing Company of Cleveland, who is a past-president of The American Society of Mechanical Engineers.

It is planned to develop a set of flasks of standard ranges of size, and recommended standard details, each to fit a standard size and design of pattern plate for use in connection with the roll-over type of molding machine.

It is thought that the results of the activities of the Joint Committee will be of especial value in shops doing miscellaneous work, in avoiding the making of new flask equipment when the molding machine is used.

Valve Standardization Postponed

THE American Engineering Standards Committee announces that it has decided to postpone indefinitely the conference on the standardization of valves, which has been under discussion during the past two years. The postponement is taken as the result of a request to this effect by the Manufacturers' Standardization Society of the Valves and Fittings Industry.

The subject of valve standardization originated with the American Engineering Standards Committee in a formal request by the Panama Canal in 1922. Since that time there has been a considerable volume of correspondence in regard to the matter; for example, in reply to a questionnaire sent to members of professional divisions of The American Society of Mechanical Engineers requesting suggestions of subjects for simplification, standardization and simplification of valves was one of the items most often proposed. Practically all of the proposals have included the standardization of face-to-face dimensions in order to insure interchangeability of

different makes of valves in pipe lines, and to make it possible, for example, to lay out pipe installations without the necessity of determining beforehand what make of valve is to be used.

The action in postponing the conference is in accordance with the announced policy of the American Engineering Standards Committee that it will not act as an initiating body, and that it undertakes work on a project only upon a formal request by a responsible body and then only after the Committee has assured itself that it is the consensus of industry that it is desirable that the work should go forward.

Standardization of Transmission Chains and Sprockets

THE Joint Committee on the Standardization of Transmission Chains and Sprockets, which contains representatives of the Society of Automotive Engineers, The American Society of Mechanical Engineers, and the American Gear Manufacturers' Association, has recommended that its personnel be increased and its work be broadened into that of a regular sectional committee under the procedure of the American Engineering Standards Committee, functioning under the joint sponsorship of the three above-named organizations. This recommendation has been approved by the American Engineering Standards Committee. The scope of the project which the societies will carry forward under the regular sectional committee organization has been tentatively drafted as follows: Formulation of American standards for transmission roller chains and sprockets teeth based on the standards already adopted by the Society of Automotive Engineers, The American Society of Mechanical Engineers, and the American Gear Manufacturers' Association; and the study of the possibilities of standardizing the so-called "silent" type of transmission chains and sprockets.

District of Columbia Adopts National Fire-Hose Threads

THE work of rethreading to the National (American) Standard all fire hydrants and hose fittings in the District of Columbia has recently been completed.

It is gratifying to note the progress that is being made in this field of standardization. The National Board of Fire Underwriters and the Bureau of Standards are glad to give assistance by the loan of rethreading tools, and by giving demonstrations of their proper use, whenever such service is practicable.

Standardization of Threads Used on Valves of Compressed-Gas Cylinders

ON account of the importance of the ready refilling of cylinders for storing compressed gas, the U. S. War Department has requested the American Engineering Standards Committee to undertake the unification of threads used on the valves fitted to such cylinders.

The Department points out that probably very little inconvenience is caused where cylinders are used locally and always returned to the same company for refilling, but that "in the case of the War Department it is sometimes necessary to send these cylinders to points far distant from the plants of the company from which they were originally secured. Refilling is then a matter of considerable inconvenience, and it has been necessary in some cases to furnish special adapters for refilling." The letter goes on to suggest that there are probably a number of commercial companies whose operations cover a wide geographical area, which also experience the same difficulty in the refilling of their compressed-gas cylinders.

It is interesting to note that there are at present eight sizes of valve outlets for hydrogen cylinders, ranging from 0.8125 to 0.904 in., at least five sizes for carbonic gas cylinders, four for acetylene, and three for nitrogen.

Another matter of standardization suggested in this same connection is the safety precaution of using left-hand threads for cylinders containing inflammable gases, and right-hand threads for non-inflammable gases. A number of gas manufacturers have tried to put this plan into actual practice, but it is not yet universal.

Standardization in the Petroleum Industry

THE American Petroleum Institute has just issued two standards, as follows: No. 3–1924, Dimensional Standards of Cable Drilling Tool Joints; and No. 5–1924, Specifications for Steel and Iron Pipe for Oil Country Tubular Goods. No. 3 includes a detailed dimensional standardization of the tool joints, including the questions of tolerances, basic thread form, pitch and taper of thread, recommended practice in turning of threads, marking of joints, and gaging. No. 5 covers lap-welded and seamless steel and iron tubular goods for oil-country purposes, covering line, drill, and drive pipe, casing and tubing, including specifications on method of manufacture, chemical properties and tests, physical properties and tests, standard weights and variations therefrom, workmanship and finish, methods of gaging and tolerances on gages with reference to the American Standard Pipe Thread; and inspection and rejection. The standard includes diagrams showing the essential dimensions of sizes of casing from $4^{3}/_{4}$ in. to $24^{1}/_{2}$ in.

The Institute has provided for the use of an official monogram by manufacturers making or selling articles in conformity with A.P.I. specifications. Arrangement is made for the issuance of a certificate of authority by the general secretary of the Institute, permitting the use of the official monogram for this purpose.

Standardization of Manhole Frames and Covers

AS THE result of a request from the Division of Simplified Practice, a sectional committee on the standardization of manhole frames and covers is being organized under the procedure of the American Engineering Standards Committee. The Telephone Group, consisting of the Bell Telephone System and the U. S. Independent Telephone Association, are acting as sponsors for the undertaking, and the American Society of Civil Engineers has been invited to associate itself in the work as joint sponsor. The Sectional Committee will contain representatives of the utility associations and other organizations interested in the subject.

As the result of a preliminary survey through extensive correspondence and a preliminary conference of interested organizations, the Division of Simplified Practice developed the fact that the need for simplification or standardization of practice was widely recognized. For example: One foundry company found that it is now manufacturing 140 types of circular frames and covers, in addition to many square and rectangular types, a condition requiring the carrying of a stock of 2000 patterns and involving an extraordinarily high seasonal variation in output.

These conditions bring out with striking clearness one of the important advantages of standardization, which is that it stabilizes production and employment by broadening the possible market, and by making it safe for the manufacturer to accumulate stock during periods of slack orders to an extent which would not be safe with an unstandardized product.

An Economic Basis for Sizes

A SYSTEM by which size series of all sorts of standards may be established according to a sound scientific principle is under consideration by a committee recently appointed by the American Engineering Standards Committee to study the possibilities of similar systems which are enlisting the interest of many engineers of the industrial countries of Europe, particularly in the mechanical and electrical engineering fields.

These series, which are called "preferred numbers," seek to provide a consistent, systematic basis for sizes, capacities, and ratings by setting up a series in which each number is a definite and uniform percentage larger than the one preceding it. Thus, 10, 16, 25, 40, 64, 100, 160, 250, 400, etc., where each size is about 60 per cent larger than the preceding, is a series of such preferred numbers. These same numbers might be used for the widest variety of articles.

The subject is presented and discussed in detail in various papers and reprints which can be obtained from the A.E.S.C. Some of these treat the subject from the popular point of view, and others from the more scientific viewpoint of the standardization expert.

C. E. Skinner, assistant director of engineering of the Westing-

house Elec. & Mfg. Co., and now chairman of the A.E.S.C., is chairman of the Preferred Numbers Committee and K. H. Condit, editor of *American Machinist*, is vice-chairman.

A working sub-committee, under the chairmanship of L. P. Alford, editor of *Management and Administration*, will take up the study of the theory of size-standardization systems and the principles of geometric series, giving due consideration to the psychologic and economic questions involved in the development of a practical preferred-numbers scheme applying to items of engineering equipment and tools, and will make general recommendations regarding the methods to be used in putting such series to work, which will ultimately be proposed for general adoption in American engineering and industry.

The members of this working committee are Messrs. L. P. Alford, Chairman (Society of Industrial Engineers), L. A. Hazeltine (Institute of Radio Engineers), F. T. Llewellyn (Am.Soc.C.E.), C. T. Myers (S.A.E.), Walter I. Slichter (Columbia University), and F. R. Still (A.S.M.E.).

It is hoped that the conclusions reached by this group will enable the General Preferred Numbers Committee to proceed without delay in making available to American industry this important tool of the standardization engineer in the form of a science of size standardization. The A.E.S.C. has available for the information of those interested, a reprint giving the specific problems and studies that have been assigned to the several members of the working committee.

Correspondence

CONTRIBUTIONS to the Correspondence Department of "Mechanical Engineering" are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on articles or policies of the Society in Research and Standardization.

The Need for Cheaper Hardness Tests

TO THE EDITOR:

Mr. Whittemore in his letter published on page 223 of MECHANICAL ENGINEERING for March states a long-felt need for a rapid, accurate, hardness tester on production work. He states further: "If an image of the impression magnified many times could be projected on a ground-glass screen having a suitable scale, the measurements would be more easily made."

We have had the difficulty mentioned by Mr. Whittemore, in getting accurate readings with the usual depth and width methods

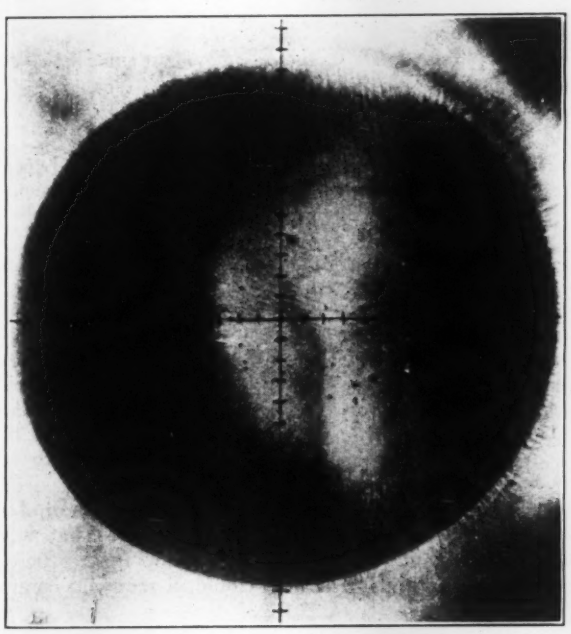

FIG. 1 PHOTOGRAPH OF BALL IMPRESSION WITH SCALE MARKED THEREON

for Brinell hardness, and are now making such readings by means about the same as suggested in the above paragraph. Our procedure is as follows:

The steel samples are quickly smoothed on a disk (No. 00 emery cloth) and the Brinell impression is made with a Hultgren-type ball at 3000 kg. They are then placed in succession on the horizontal stage of a metallurgical microscope with strong illumination. The image of the Brinell impression is projected to the ground glass at a definite bellows extension, and the diameter is read on crossed scales attached to the ground glass, readings being taken vertically and horizontally to allow for any slight distortion, and the average used. The scales were prepared by placing an accurate millimeter rule on the stage and marking the projected millimeter lines on the ground glass. Millimeters are divided into tenths, and further, if required.

In place of the ground glass, the image may be projected on a suitably marked screen.

We find this method of reading accurate and rapid, and attended by no eye strain.

The accompanying illustration (Fig. 1) is reproduced from a photograph of an impression on high-speed steel. To illustrate the method described, an approximate scale has been drawn on the print. Owing to poor illumination, one side of the print is not very distinct, but the actual image on the ground glass is sufficiently sharp for accurate readings.

EDWIN K. SMITH.[1]

Birmingham, Ala.

Critical Pressures in Lubricating-Oil Films

TO THE EDITOR:

The pendulum feature of Mr. Linsley's testing machine[2] which insures no displacement of the center of gravity with change in load is, in the writer's opinion, the only true method of designing bearing-testing apparatus. This method is similar to that of Martens. The defect in the machine used by the author lies in the fact that pressure is applied to the top and bottom halves of the bearing simultaneously. This never occurs in practice. The machine designed by P. L. Irwin in the Westinghouse Research Laboratory overcomes this defect while still retaining the pendulum feature. A second point of criticism of the apparatus is the small size of the bearing used, namely, 2 in. diameter. Since such data are to be applied to large bearings, it is unfortunate that this experimental bearing was not at least $3^1/_2$ to 4 in. in diameter.

With regard to the results obtained, it is interesting to note that the values of the critical bearing pressures are much higher than was previously believed possible. It must be observed, however, that our previous knowledge of this phenomenon was based largely on the results obtained by R. H. Moore. These again were obtained on an even smaller bearing, namely, 1.289 in. in diameter and $1^1/_2$ in. long. The results obtained by the author seem to invalidate those obtained by Moore. Probably these latter results were influenced to a great degree by metallic particles breaking off and being carried round by the oil, thereby establishing electrical contact. This belief is strengthened when it is known that Moore did not seem to make any provision for filtering the oil, but used the same oil continuously. Moreover, the fact that no perceptible

[1] Research Engineer Stockham Pipe and Fittings Co.

[2] See MECHANICAL ENGINEERING, vol. 97, no. 2, February, 1925, p. 110.

rise in bearing temperature was observed after the film was broken down, may support this argument. On the other hand, in justice to this previous investigator it should be noted that the maximum pressure observed was 85 lb. per sq. in. at a velocity of 140 ft. per min. These conditions are far removed from those obtained in the present paper, and the interpolation shown in Fig. 5 of Mr. Linsley's complete paper, therefore, does not appear justifiable.

With regard to Nicolson's equation this was based on Sommerfeld's work. The relation $P = 40\ (dN)^{1/4}$ was deduced by him on the assumption that the bearing was running cool and without wear, and was, moreover, limited to speeds of 450 ft. per min. Since wear does actually occur in service, and since bearings do not always run cool, we can conclude that Nicolson's results are conservative. The value of the constant on the right-hand side of the above equation will be subject to modification, depending on the type of bearing employed.

J. M. LESSELLS.[1]

Equipment Used for Aerial Surveying

TO THE EDITOR:

The article entitled Equipment Used for Aerial Surveying in the March issue of MECHANICAL ENGINEERING is very interesting, since it describes the operations of some of the automatic cameras used in aerial photographing. It is obvious that much difficulty must have been encountered in their development, and those responsible are to be commended for the dependable mechanical operation of such cameras.

However, so much has been written about aerial cameras and their mechanisms that one might believe the camera to be the most difficult instrument to produce of all those used in the making of aerial surveys. As a matter of fact, maps were made from photographs by European army officers more than 70 years ago, and the same scientific principles were used as are applied today, as well as the same method of determining the projection of the lens axis on the photograph. Therefore the great improvements in the present cameras are in the mechanical parts which automatically feed and expose the pictures. The need for these changes is due to the use of the airplane as a vehicle.

In the early photographic surveys, cameras were set at stations of high elevation very much the same as were transits. The angles of the photographic planes were predetermined relative to each other and to the vertical planes containing the base lines between their stations. This method contained no unknown quantities in respect to the position of the photographic plane such as exist in the pictures taken in airplanes. However, considering the speed at which pictures can be made in an airplane and that the views are practically horizontal, it is obvious that the new method is vastly superior.

Unless the views are horizontal or are reprojected to the horizontal and corrections are made for errors due to ground-elevation changes, accurate maps cannot be made from them. The joining together of a series of horizontal pictures, no matter how accurately, does not constitute an accurate map, as each photograph will contain errors in scale due to ground relief.

Mr. Robinson calls attention to the stereocomparator, the autocartograph, and the stereoplanigraph made by European companies and also mentions "domestic devices" which he says will put in 20-ft. contours. Perhaps "American" would better designate these domestic instruments. The European companies and the American company responsible for the development of their mapping instruments consider the camera the least difficult of all the problems involved in map making. The precision parts of a camera are fixed and its total weight rarely exceeds 75 lb., whereas some of the instruments used for mapping after the photographs are made weigh several thousand pounds and all of the moving parts must be constructed to permit of the most precise measuring. On the American meachines one-half thousandth of an inch can be measured with the greatest speed and ease.

The tilt, which is the unknown angle of the plane of projection at the time of exposure and is mentioned by the author as the bugbear, is the most serious problem met in aerial surveying. Since 1916 the writer has been interested in the development of instruments for use in aerial mapping, and since the beginning the problem of solving the tilt angle of each plate has been the most difficult. The European companies and especially the American company made exhaustive experiments with the gyroscope as a means of stabilizing the camera axis in the vertical or to record the angle of tilt, but the results obtained were not within the necessary limits. The use of the gyroscope was abandoned by the American company as it is believed that due to the disturbing forces introduced by the airplane the gyroscopic principles will not permit of sufficiently accurate solution. When it is considered that a tilt of 5 min. may give an error of about 15 ft. in the ground elevation determined directly from a photograph, the needs of solving the tilt angle can be readily understood.

It is the writer's understanding that the European companies no longer use the gyroscopic principle to find the tilt angle. They have made extensive studies of the angle solution by the three-point method, but he has been informed that none of them have contracted to make maps by a process of drawing the contours directly from photographs taken in an airplane. His own experience with the three-point problem has been that with the mechanical measuring instruments available it was not possible to reduce the tilt angle to an amount required for accurate mapping.

The company responsible for the development of American instruments uses an entirely different method of angle correction and its process of making maps approaches the theoretical principles by methods that differ from those used by other concerns. The development of the process and the instruments used therein has taken about eight years, and, including the cost of making the instruments, several hundred thousand dollars were expended before reaching the stage where it could produce maps with contours drawn directly from the photographs. It is believed that the American company is the first to produce maps, at contract prices, which contain contours drawn directly from photographs. It is a fact that no others in the United States have produced such aerophotographic maps.

The drawing of the contours requires the most precise measuring, but it is easily accomplished with surprising speed by the mechanical instruments and no guesswork nor interpolation is necessary as in the method of using the stereoscope shown in Fig. 7 of Mr. Robinson's paper.

EDWARD H. CAHILL.[1]

Philadelphia, Pa.

Steel Bridges

THE following specifications for steel bridges are before the American Engineering Standards Committee:

General Specifications for Steel Railway Bridges
Specification for Movable Railway Bridge
Specifications for Design and Construction of Steel Railway Bridge Superstructure
Specifications for Design and Construction of Steel Highway Bridge Superstructure.

The first two were submitted by the American Railway Engineering Association and the last two by the American Society of Civil Engineers. These specifications were referred to a Special Committee for recommendation containing representatives of the various organizations interested in railway and highway bridgework.

At a meeting of the A.E.S.C. Executive Committee on January 8 the following recommendation was approved:—That work on highway bridges should be allowed to develop further before attempting national standardization through a sectional committee.

A Correction

On page 275 of the April issue of MECHANICAL ENGINEERING there was published a discussion by E. J. Flather on the Application of Engineering Principles to Economic Problems in the Textile Industry. The Mr. Flather who took part in the discussion was Frederick A. Flather, treasurer and manager of the Boott Mills Boston, Mass., and not E. J. Flather.

[1] Engr., Research Laboratory, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa. Mem. A.S.M.E.

[1] Ch. Engr., Arthur Brook, Jr., Tool and Manufacturing Works. Mem. A.S.M.E.

Test Code for Refrigerating Systems

Tentative Draft of a Code in the Series of Nineteen Being Formulated by the A.S.M.E. Committee on Power Test Codes

THE Test Code for Refrigerating Systems has been developed by a Joint Committee composed of representatives of The American Society of Refrigerating Engineers and The American Society of Mechanical Engineers, under the chairmanship of Prof. R. M. Anderson. The other members of this Committee are L. Block, N. H. Hiller, G. A. Horne, F. E. Matthews,[1] E. F. Miller, P. Neff, T. S. Shipley, and G. T. Voorhees.[2]

The Committee on Power Test Codes was reorganized in 1918 by the Council of The American Society of Mechanical Engineers to revise and enlarge the Power Test Codes of the Society published in 1915. This committee consists of a Main Committee of twenty-five members, having for its chairman Fred R. Low, Past-President, and nineteen Individual Committees of specialists, who are drafting test codes for the various prime movers and auxiliary apparatus which constitute power-plant equipment.

Suggestions for corrections and additions to this test code will be welcomed by the Committee and the cooperating societies from those who are especially interested in the manufacture, use, and testing of refrigerating systems. These comments should be addressed to the Chairman of the Committee, in care of The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

Introduction

1 The Test Code for Refrigerating Systems is intended for use in the determination of the performance of compression systems in which compressors of the reciprocating type are used as well as absorption machines. In so far as the fundamental operations of all the systems are in common, general rules will be laid down and where the systems differ separate rules will be given. For the test of the driving element in compression systems, the A.S.M.E. Power Test Codes for Steam Engines, Steam Turbines, Internal-Combustion Engines, etc. should be followed.

Objects

2 In accordance with the "Code on General Instructions" the object of the test should be first determined and recorded. If the object relates to the fulfillment of a contract guarantee, an agreement should be made between the interested parties concerning all matters about which disputes may arise (see "Code on General Instructions," Par. 6), and a full statement of the agreement entered in the report of the test.

Measurements

3 The principal measurements and quantities determined in a test are:

(*a*) The quantity of the refrigerant circulated
(*b*) The various temperatures of the refrigerant in the cycle
(*c*) The various pressures of the refrigerant in the cycle
(*d*) The energy required to operate the driving element and the various auxiliary apparatus
(*e*) The various temperatures of condensing and cooling water
(*f*) The quantity of condensing and cooling water
(*g*) Quantity, quality, and pressure of steam used in the steam cylinder or generator
(*h*) Principal dimensions of driving element (see appropriate code)
(*i*) Quantity of oil passing through the compressor
(*j*) Quantity of composition and density of brine used
(*k*) Temperature of brine entering and leaving the evaporator
(*l*) Quality of liquor used in absorption plants.

Instruments and Apparatus

4 The instruments and apparatus necessary in carrying out the test are:

(*a*) Suitable meter for measuring liquid refrigerant on the high or intermediate pressure side where same passes to the expansion coils of the brine cooler or elsewhere
(*b*) Platform scales and suitable tanks for measuring water and condensed steam
(*c*) Water meters, calibrated tanks or tank and platform scale for measuring condensing and cooling water
(*d*) Pressure gages and vacuum manometers including a suitable U tube for mercury column to be connected at the low pressure suction of the compressor. It is recommended that this be used in all cases rather than a pressure or vacuum gage for suction pressures under 20 pounds gage
(*e*) Calibrated thermometers and thermometer mercury wells of sufficient lengths to extend beyond the centers of the pipes. Thermometers used for taking temperatures of brine shall be graduated in 1/10 deg. fahr. and readings estimated to 1/100 deg. fahr.
(*f*) Barometer and psychrometer when necessary
(*g*) Revolution counter or other accurate speed measuring device
(*h*) Graduated stroke indicator for direct acting pumps
(*i*) Picnometer, Mohr-Westphal balance, or calibrated hydrometer for specific gravity of brine
(*j*) Calorimeter for determining the quality of the steam
(*k*) Steam and ammonia indicator
(*l*) Planimeter
(*m*) Dead weight gage tester
(*n*) Appropriate instruments for measuring current consumption of motor-driven machines.

The directions for the use, calibration and accuracy of the instruments and apparatus enumerated above are given in the various sections of the "Code on Instruments and Apparatus."

Preparation

5 Paragraphs 7 to 11 of the Code on General Instructions should be read, carefully studied and conformed to wherever they apply. The dimensions and the physical conditions of all parts of the plant essential to the object of the test should be accurately determined and carefully recorded.

6 The dimensions of the compressor and engine cylinder and the pump plungers or cylinders should be accurately measured and recorded in accordance with Paragraph 6 of the A.S.M.E. "Test Code for Reciprocating Steam Engines."

7 All measuring devices should be installed and in the case of the meters for measuring water or brine a means of calibrating by direct weighing or checking by calibrated tanks should be provided. The meter for measuring the liquid refrigerant shall be calibrated by means of a closed tank or receiver of known volume. This

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NOTE: Messrs. Matthews and Voorhees have not signed this report but have requested the privilege of filing individual minority statements which are reproduced below.

[1] FRED E. MATTHEWS. I submit the following minority report inasmuch as limiting the metering of refrigerant to the liquid phase may remove incentive to the development of methods for measuring such refrigerants in the vaporous phase, a procedure which I am convinced is not without its advantages. I wish to go on record as being opposed, for the time being at least, to the phraseology of Par. 20 of the Code and in favor of the term *suitable meter* not limited by the term *liquid*.

[2] GARDNER T. VOORHEES. It is with regret that I report that I feel that this proposed code is not proper for our industry. Briefly my reasons therefor are as follows:

(1) It conflicts with the already adopted standard-ton ratings.

(2) It depends on metering the liquid refrigerant, not yet proven to me to be reliable.

(3) It depends on thermodynamic tables and usages that to my mind are open to question,—see my paper Thermodynamic Tables and Charts as printed in *Ice and Refrigeration* for January, 1925.

(4) It is too verbose and lengthy, and not practical.

(5) Simpler formulas more easily understood by the average man should be used.

(6) Absorption-machine matters are not sufficient and yet are too lengthy in many respects.

(7) Cooling-tower matters should not form any part of a preliminary code of this nature.

(8) Such a code would do more harm than good in leading prospective testers to think that tests were beyond their capacity.

(9) Exhibition of such a code to a plant owner would cause him to be scared out of making or allowing such test to be made at his plant because of its implied complexness and probable interference with his business.

(10) Such a code should come after a completed standard-tonnage amplification, for otherwise it will be bound to conflict and be at variance therewith and so, later on, have to be discarded and discredited.

(11) The other constructive features of my minority report, not given above, are as follows: (*a*) Get out a brief practical code in harmony with standard-tonnage matters, touching the high spots only; (*b*) get this brief practical code actually used to find out if it fits and then make it fit and when required, amplify it; and (*c*) later on when we have outgrown it, get a larger code to fit our enlarged requirements.

volume should preferably be determined by weighing the water which fills the tank or receiver. In the ordinary plant a liquid receiver may be used for this purpose.

8 The thermometer wells should be of steel for ammonia lines, and bronze for brine lines, and should extend into the pipe a sufficient distance so that the bulb of the thermometer will extend at least to the center of the pipe. When comparisons of temperatures are being made it is extremely important that the immersion in the well should be identical in all cases. These wells should be filled with mercury to the point indicated on the stem of the thermometer. Insulation on the cold lines should extend even to the top of the well, and the thermometers pass through corks fitted to the wells and bored to accommodate the thermometers. The thermometer well must be placed at least 10 feet away from brine coolers or pumps so that the solution has uniform temperature where the readings are taken. Electric resistance thermometers or thermocouples may be used in taking temperatures of brine as a check on mercury thermometers.

9 In testing a plant where the load is light a brine heater or a heater using waste condensing water flowing over the evaporating coils should be used.

10 For ammonia a special steel indicator must be provided which has steel indicator cocks with short separate connections to the ends. The indicator should be provided with a stop so that a light spring may be used for studying suction conditions.

11 In ammonia absorption systems the anhydrous ammonia should not contain over 3 per cent moisture. Samples should be drawn before and immediately after the test and determinations of moisture made.

Operating Conditions

12 The operating conditions should conform to the object of the test and should prevail throughout the trial as pointed out in Par. 23 of the "Code on General Instructions." An agreement should be reached as to which of the interested parties is to supply and install the brine heater, if necessary, and all other apparatus required for the tests. In commercial tests the allowable percentage of difference in the heat balance between the water and the liquid must be stated.

Starting and Stopping

13 The plant should be operated a sufficient length of time prior to the starting of the test to insure uniformity of conditions and, when these conditions are obtained, the test should be started and continued as stated in Par. 14 of this code. It is essential to the accuracy of the test that all parts of the plant contain the same amount of heat estimated above some datum at the end as at the beginning of the test. To accomplish this all vessels containing liquid refrigerant should be supplied with suitable gage glasses so that the same quantity of fluid may be distributed alike at the beginning and end of the test and the quantities and temperature of the fluids in the various parts maintained as uniform as possible.

Duration

14 The test should be continued over a period of time not less than eight hours.

Records

15 The data should be taken and recorded in the manner prescribed in the "Code on General Instructions," Pars. 24 to 35. Fifteen minute readings will be sufficient except where there is considerable fluctuation in the readings in which case more frequent readings must be taken to insure good averages.

16 Each indicator card should be marked with the date, time of day, cylinder and end of cylinder, and identification mark and strength of indicator spring, as pointed out in the "Test Code for Reciprocating Steam Engines," Par. 20. To assist in the uniformity of operation a chart should be plotted during the test of the principal quantities including the estimated tonnage, as pointed out in Par. 39 of the "General Instructions."

17 The data and results should be tabulated in accordance with the form shown in the following tables, adding items not provided for and omitting items not needed to conform to the object in view. Unless otherwise indicated the items refer to the numerical readings which are recorded in the log.

Calculation of Results

18 The now generally adopted recommendations of the Joint Committee of The American Society of Mechanical Engineers and American Society of Refrigerating Engineers on Standard Tonnage Basis for Refrigeration are as follows:

a A standard ton of refrigeration is 288,000 B.t.u.

b The standard commercial ton of refrigeration is at the rate of 200 B.t.u. per min.

c The standard rating of a refrigerating machine[1] using liquefiable vapor is the number of standard commercial tons of refrigeration it performs under adopted refrigerant pressures.[2]

19 The capacity of the system shall be expressed in tons of refrigeration per 24 hours as calculated from the weight of liquid refrigerant and the amount of available cooling effect produced in the evaporator. This method shall be employed in the case of all refrigerants where the physical properties have been determined and where tables of such properties are recognized as sufficiently accurate. The tables of thermodynamic properties employed shall be those adopted and published by The American Society of Refrigerating Engineers.

20 The weight of refrigerant circulated shall be determined by a suitable liquid meter as prescribed in the A.S.M.E. Code on Instruments and Apparatus. As an alternate method the weight of liquid refrigerant shall be calculated from the volume as obtained from a pair of calibrated receivers or by direct weighing.

21 The amount of available refrigerating effect shall be the weight of refrigerant circulated per hour multiplied by the difference in heat content on entering and leaving the evaporator. Where there is more than one evaporator in which different pressures exist, the weight of refrigerant to each evaporator and the total heat from the vapor must be determined separately and the total refrigerating effect may then be computed by the following formula:

$$Q_e = W_a (H_e - h_e)$$

where Q_e = total refrigerating effect
W_a = weight of anhydrous refrigerant circulated in pounds per hour
H_e = total heat in the vapor leaving the evaporator
h_e = total heat in the liquid at the expansion valve.

22 The refrigeration effect expressed in standard commercial tons of refrigeration is

$$R.E. = \frac{Q_e}{12{,}000}$$

23 *Theoretical Horsepower Required to Compress Adiabatically.* The work done in the cylinder of the compressor per pound of ammonia circulated expressed in thermal units may be found by referring to either the Mollier Chart or the tables adopted and published by The American Society of Refrigerating Engineers.

$$\text{hp.} = \frac{(H_o - H_i) \times W_a \times 778}{33{,}000}$$

where H_o = heat content of vapor after adiabatic compression
H_i = heat content at compressor inlet
W_a = weight of ammonia circulated, pounds per hour.

24 *Gross or Brake Horse Power.* See Test Code for Displacement Compressors and Blowers, Par. 13.

25 *Electrical Horsepower.* See Test Code for Displacement Compressors and Blowers, Par. 14.

26 *Volumetric Efficiency.* See Test Code for Displacement Compressors and Blowers, Par. 15.

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[1] A refrigerating machine is the compressor cylinder of the compression refrigerating system, or the absorber, liquor pump, and generator of the absorption refrigerating system.

[2] These pressures are measured outside and within 10 ft. of the refrigerating machine, distances which are measured along the inlet and outlet pipes, respectively; (*a*) the inlet pressure being that which corresponds to a saturation temperature of 5 deg. fahr. (—15 deg. cent.) and (*b*) the outlet pressure being that which corresponds to a saturation temperature of 86 deg. fahr. (30 deg. cent.)

27 *Mechanical Efficiency.* Mechanical efficiency is the ratio of the indicated horsepower in the compressor cylinders to the indicated horsepower in the power cylinders in the case of a steam-driven or internal-combustion-driven compressor, and to the brake horsepower delivered to the shaft in the case of a motor-driven machine.

28 *Compression Efficiency.* Compression efficiency is the ratio of work required to compress adiabatically all the vapor delivered by the compressor to the work done within the compressor cylinder as shown by the indicator cards.

29 *Overall Efficiency.* The method of computing the overall efficiency is described in the Test Code for Displacement Compressors and Blowers, Par. 18.

30 *Condenser Performance.* The condenser is required to remove the total heat of the vapor drawn into the compressor plus the heat of compression. It is therefore incorrect to consider the removal of 12,000 B.t.u. per hour by the condensing water as equivalent to the standard commercial ton as produced in the evaporator. The total heat removed by the condensing water shall be calculated from the observed data when the enclosed type of condensers, either shell and tube or double pipe, are used. The total heat may also be calculated from the quantity of refrigerant circulated. In this case

$$Q_1 = W_a (H_c - h_c)$$

where Q_1 = heat removed per hour
H_c = heat content of vapor entering condenser
h_c = heat content of liquid leaving condenser
W_a = weight of refrigerant condensed per hour.

31 *Determination of Heat Transfer in Condensers.* The work done in the condenser may be divided into three stages: first, the removal of superheat; second, the liquefaction of the refrigerant; and third, the sub-cooling of the condensed liquid. It is therefore to be expected that the rate of heat transfer is not the same in all parts of the condenser. The logarithmic mean difference is based upon a constant temperature of liquefaction throughout the condenser on the assumption that the heat transfer is uniform throughout the condenser. While the calculation of heat transfer per square foot of refrigerant surface per hour per degree of logarithmic mean difference does not give entirely satisfactory results, the determination of heat transfer shall be calculated in this manner.

$$\text{Log. mean difference} = \frac{t_o - t_i}{\log_e \frac{t_e - t_i}{t_e - t_o}}$$

where t_e = temperature of liquefaction corresponding to condenser pressure
t_i = temperature incoming water
t_o = temperature outgoing water.

If a complete condenser test is to be made the Test Code for Condensing Apparatus and the Code on Instruments and Apparatus should be carefully studied.

32 *Evaporator Performance.* The evaporator performance shall be calculated from the observed data. In this case

$$Q_e = W_a(H_e - h_e)$$

in which

Q_e = heat removed per hour
H_e = heat content of vapor
h_e = heat content of liquid entering expansion valve
W_a = weight of refrigerant entering evaporator in pounds per hour.

33 *Determination of Heat Transfer in Evaporator.* (*a*) Brine Coolers. Brine-cooler performance shall be expressed in terms of heat transfer per square foot of cooling surface per hour per degree of logarithmic mean difference.

$$\text{Log. mean difference} = \frac{t_i - t_o}{\log_e \frac{t_i - t_v}{t_o - t_v}}$$

where t_o = temperature of brine out of evaporator
t_i = temperature of brine to evaporator
t_v = temperature of vaporization corresponding to evaporator pressure.

(*b*) The performance of ice tanks and all other forms of expansion coils or apparatus will not be specifically covered in this Code, which is intended to include the main items of the refrigerating cycle rather than the products of the cycle.

34 *Pump Horsepower.* The water-horsepower output at observed total suction and discharge pressure is

$$\text{W.hp.} = \frac{(\text{lb. of liquid per minute}) \times (\text{total head in ft.})}{33{,}000}$$

The gross or brake horsepower input shall be observed for all pump-driving elements and the efficiencies calculated.

35 *Heat Balance.* A heat balance shall be made of the refrigerating cycle, of which the following is an illustration of all the items required in a compound-cycle compression system. As a heat balance is impossible unless extreme care has been taken in making the measurements, it will be found necessary to have most accurate thermometers for observing the temperature of water on and off condensers as well as for taking temperature of brine. It is also necessary to have indicator cards taken at uniform intervals, at least every thirty minutes in order to determine the heat equivalent of work done in the compressor.

36 The general formulas for heat balance are as follows:

Compression Cycle: $Q_e + Q_w = Q_1 + Q_3$
Absorption Cycle: $Q_e + Q_s = Q_1 + Q_2 + Q_3$

where Q_e = heat absorbed by evaporating refrigerant
Q_w = heat equivalent of work in compressor
Q_s = heat imparted by steam in generator
Q_1 = heat rejected in condenser
Q_2 = heat rejected in absorber
Q_3 = heat rejected or radiated in addition to Q_1 and Q_2.

37 For purposes of illustration the following list of quantities involved in the computation of the heat balances of compound compression systems is given.

Heat Absorbed (B.t.u. per hour)	Heat Rejected
a Heat absorbed in evaporator	*a* Heat rejected by hot surfaces of low-pressure compressor
b Heat entering evaporator insulation	*b* Heat rejected from low-pressure discharge main between low-pressure compressor and intermediate vapor cooler
c Heat absorbed in low-pressure suction main	*c* Heat rejected in intermediate vapor cooler
d Heat absorbed in low-pressure suction trap	*d* Heat rejected to engine room by intermediate vapor cooler
e Heat equivalent of work done in compressor	*e* Heat rejected in discharge main from intermediate vapor cooler to intermediate liquid receiver
f Heat absorbed from engine room through cold surface of low-pressure compressor	*f* Heat rejected by hot surfaces of high-pressure compressor
g Heat absorbed through surface of intermediate liquid receiver	*g* Heat rejected by high-pressure discharge main and oil separator between machine and condensers
h Heat absorbed through surface of intermediate-pressure liquid line	*h* Heat rejected in ammonia condensers
i Heat absorbed from engine room through surface of high-pressure suction main	*i* Heat rejected in liquid cooler
j Heat absorbed through cold surfaces of high-pressure compressor	*k* Heat absorbed or rejected through condenser shells
	l Heat absorbed or rejected through receivers
	m Heat absorbed or rejected in high-pressure liquid line.

Data and Results

38 Before writing the final report, Par. 20 of the "Code on General Instructions" should be carefully read. The data and results should be reported in accordance with the forms given in Tables 1, 2, 3, and 4, adding lines for data not provided for or omitting those not required. Unless otherwise indicated, the items should be the averages of all observations.

A—COMPRESSION REFRIGERATING SYSTEMS

TABLE 1 DATA AND RESULTS OF TEST ON POWER-DRIVEN REFRIGERATING UNIT

	General Information		
(1)	Date of test		
(2)	Location		
(3)	Owner		
(4)	Builder		
(5)	Test conducted by		
(6)	Object of test		
	Description, Dimensions of Compressor, Condenser, Etc.		
(7)	Type of compressor (single or multiple stage, and kind of refrigerant)		
(8)	Type of compressor valves		
(9)	Method of driving compressor		
(10)	Method of volume control		
(11)	Rated discharge pressure	lb. per sq. in.	
(12)	Rated speed	r.p.m.	
(13)	Rated displacement	cu. ft. per min.	
(14)	Rated output expressed in standard tons of refrigeration		
(15)	Type of intercoolers		
		1st Intercooler	2nd Intercooler
(16)	Area of water-cooled surface	sq. ft.	
		1st Stage	2nd Stage
(17)	Diameter of compressor cylinders	in.	
(18)	Stroke of pistons	ft.	
(19)	Diameter of piston rods or tail rods	in.	
(20)	Clearance in terms of piston displacement	per cent	
		1st Stage	2nd Stage
	(*a*) Clearance, head end		
	(*b*) Clearance, crank end		
	(*c*) Clearance, average		
(21)	Cylinder ratio based on piston displacement		
	(*a*) 1st stage to 2nd stage		
		1st Stage	2nd Stage
(22)	Horsepower constant, cylinder:		
	(*a*) Head end: (stroke × net piston area ÷ 33,000)		
	(*b*) Crank end: (stroke × net piston area ÷ 33,000)		
		1st Stage	2nd Stage
(23)	Area of compressor cylinder jacketed surface	sq. ft.	
(24)	Length and cross-sectional area, intake pipe	ft.	
(25)	Diameter of final discharge pipe	in.	
(NOTE: For description, dimensions, etc., of compressor-driving element, see Tables 2, 3 or 4.)			
(26)	Type of condenser		
(27)	Area of condenser surface on refrigerant side	sq. ft.	
(28)	Type of evaporator		
(29)	Area of evaporator surface on refrigerant side	sq. ft.	
(30)	Type of water pumps		
(31)	Size of water pumps, No. 1, No. 2	gal. per min.	
(32)	Type of brine pumps		
(33)	Size of brine pumps, No. 1, No. 2, No. 3	gal. per min.	
(34)	Type of cooling tower		
(35)	Rated capacity of cooling tower		
(36)	Type of liquid after cooler		
(37)	Cooling surface of liquid after cooler	sq. ft.	
(38)	Type of intermediate liquid cooler		
(39)	Size of intermediate liquid cooler	diam.	height
	General Data		
(40)	Composition of brine		
(41)	Specific gravity of brine used at 68 deg. fahr. compared with water at 39.1 deg. fahr.		
(42)	Specific heat of brine used		
(43)	Specific gravity of liquid refrigerant as measured		
(44)	Kind of cooling water used (well, salt, river)		
(45)	Specific gravity of cooling water		
(46)	Specific heat of cooling water		
	Test Data and Results		
(61)	Duration of test	hr.	
	Average Pressures		
(62)	Barometric pressure	in. of mercury	
	(*a*) Corresponding absolute pressure	in. of mercury	
(63)	Pressure by mercury manometer at intake near cylinder first stage	in. of mercury	
	(*a*) Corresponding absolute pressure	lb. per sq. in.	
		1st Stage	2nd Stage
(64)	Pressure by gage in discharge pipe near cylinder, lb. per sq. in.		
	(a) Corresponding absolute pressure, lb. per sq. in.		
(65)	Pressure in intercooler by gage, lb. per sq. in.		
	(a) Corresponding absolute pressure, lb. per sq. in.		
(66)	Condenser pressure by gage, lb. per sq. in.		
	(a) Corresponding absolute pressure, lb. per sq. in.		
(67)	Pressure in evaporator, by gage, lb. per sq. in.		
	(a) Corresponding absolute pressure, lb. per sq. in.		
		No. 1	No. 2	No. 3
(68)	Pressure at inlet of cooling-water pumps by gage, lb. per sq. in.			
(69)	Pressure at outlet of cooling-water pumps by gage, lb. per sq. in.			
(70)	Pressure at inlet of brine pump by gage, lb. per sq. in.			
(71)	Pressure at outlet of brine pump by gage, lb. per sq. in.			
	Average Temperatures		
(76)	Engine-room temperature	deg. fahr.	
(77)	Condenser-room temperature	deg. fahr.	
(78)	Temperature of outside air	deg. fahr.	
(79)	Temperature of wet bulb, outside air	deg. fahr.	
		1st Stage	2nd Stage
(80)	Temperature of vapor near intake (to be measured not more than two feet from the compressor inlet and show between 6 and 12 deg. of superheat), deg. fahr.		
(80a)	Temperature of vapor from evaporator (to be measured not more than two feet from outlet), deg. fahr.		
(81)	Temperature of vapor near discharge port, deg. fahr.		
(82)	Temperature of vapor at inlet to intermediate vapor cooler, deg. fahr.		
(83)	Temperature of vapor at outlet intermediate vapor cooler, deg. fahr.		
(84)	Temperature of liquid from condensers	deg. fahr.	
(85)	Temperature of liquid from liquid receivers	deg. fahr.	
(86)	Temperature of liquid from liquid cooler	deg. fahr.	
(87)	Temperature of liquid from intermediate liquid cooler	deg. fahr.	
(88)	Temperature of liquid at measuring point	deg. fahr.	
(89)	Temperature of jacket cooling water, inlet	deg. fahr.	
(90)	Temperature of jacket cooling water, outlet	deg. fahr.	
(91)	Temperature of cooling water, intermediate vapor cooler inlet	deg. fahr.	
(92)	Temperature of cooling water, intermediate vapor cooler outlet	deg. fahr.	
(93)	Temperature of cooling water, liquid-cooler inlet	deg. fahr.	
(94)	Temperature of cooling water, liquid-cooler outlet	deg. fahr.	
(95)	Temperature of cooling water, condenser inlet	deg. fahr.	
(96)	Temperature of cooling water, condenser outlet	deg. fahr.	
(97)	Temperature of water to cooling tower	deg. fahr.	
(98)	Temperature of water from cooling tower	deg. fahr.	
(99)	Temperature of brine, brine-cooler inlet	deg. fahr.	
(100)	Temperature of brine, brine-cooler outlet	deg. fahr.	
(101)	Temperature range through brine coolers by electric resistance thermometer	deg. fahr.	
	Total Quantities		
(107)	Liquid delivered to evaporator	lb.	
(108)	Brine circulated	gal.	
	Unit Quantities		
(115)	Liquid delivered to evaporator (Item 107 ÷ Item 61)	lb. per min.	
(116)	Brine circulated (Item 108 ÷ Item 61 × 60)	gal. per min.	
(117)	Cooling water supplied to condensers	gal. per min.	
		1st Stage	2nd Stage
(118)	Cooling water supplied to jackets, gal. per min.		
(119)	Cooling water supplied to intermediate vapor cooler	gal. per min.	
(120)	Cooling water supplied to liquid cooler	gal. per min.	
	Refrigerating Output		
(121)	Available cooling effect (Q_e) see Par. 21		
(122)	(*a*) Tons of refrigeration produced (Item 121 ÷ 200)		

(*b*) Tons of refrigeration, brine method as a check (Item 116 × Item 101 × Item 41 × 8.33 × Item 42 ÷ 200)....

Speed

(126) Total number of revolutions as shown by compressor counter.....r.p.m.
(127) Revolutions per minute, Item 126 ÷ (Item 61 × 60).....
(128) Average piston speed.....

Power

(129) Indicated horsepower of compressor cylinders, whole compressor.....i.hp.
(130) Low-pressure cylinder or cylinder if single-stage:
Crank end.....i.hp.
Head end.....i.hp.
(131) High-pressure cylinder:
Crank end.....i.hp.
Head end.....i.hp.
(132) Friction horsepower, Item 144 (Table 2), or Item 133 (Table 3) — Item 129.....i.hp.

Power Input

See Tables 2, 3 or 4

Economy Results

(145) Gross or brake horsepower of compressor per ton of refrigeration.....hp.
(146) Electrical horsepower of compressor per ton of refrigeration..hp.
(147) Indicated horsepower of compressor per ton of refrigeration (Item 129 ÷ Item 122a).....hp.

Efficiency Results

Theoretical Horsepower Calculation:

	1st Stage	2nd Stage
(*a*) Total heat contained in 1 lb. vapor at suction.....B.t.u.		
(*b*) Total heat contained in 1 lb. liquid entering expansion valve.....B.t.u.		
(*c*) Available latent heat per lb. of refrigerant (Item *a* — Item *b*).....		
(*d*) Work required to compress 1 lb. refrigerant adiabatically (see Mollier chart).....B.t.u.		
(*e*) Theoretical temperature of discharge vapor (See Mollier chart)..deg. fahr.		
(*f*) Horsepower per ton for adiabatic compression.....i.hp.		
(152) Total horsepower for adiabatic compression.....		
(153) Volumetric efficiency (see Par. 26)....		
(154) Compression efficiency (see Par. 28).....		
(155) Mechanical efficiency (see Par. 27).....		
(156) Overall efficiency (see Par. 29).....		

Condenser

(157) Heat removed per minute by condensing water (see Par. 30) (Item 96 — Item 95) × Item 117 × 8.33.....B.t.u.
(158) Heat removed as calculated from refrigerant condensed as a check (see Par. 30).....
(159) Heat removed per hour, Item 157 × 60.....B.t.u.
(160) Logarithmic mean temperature diff. in deg. fahr. (see Par. 31)...
(161) Coefficient of heat transfer: K = (Item 159 ÷ Item 160 × Item 27).....

Evaporator

(162) Heat removed per minute from brine.....B.t.u.
(163) Heat removed per hour, Item 162 × 60.....B.t.u.
(164) Logarithmic mean temperature diff. = deg. fahr. (see Par. 33)..
(165) Coefficient of heat transfer:
K = (Item 163 ÷ Item 164 × Item 29).....

Auxiliary Pumps:	No. 1	No. 2
(*a*) *Brine Pumps*		
(166) Gross or brake horsepower.....b.hp.		
(167) Water horsepower (see Par. 34).....hp.		
(168) Overall pump efficiency.....per cent		
(*b*) *Water Pumps*.....b.hp.		
(170) Water horsepower (see Par. 34).....hp.		
(171) Overall pump efficiency.....per cent		

TABLE 2 ADDITIONAL ITEMS APPLYING ONLY WHEN THE DRIVING ELEMENT IS AN ELECTRIC MOTOR

DESCRIPTION, DIMENSIONS, ETC., OF COMPRESSOR DRIVE

(47) Type of motor.....
(48) Rated power of motor.....
(49) Volts.....
(50) Amperes.....
(51) Phase.....
(52) Cycles.....
(53) Revolutions per minute.....
(54) Type and rating of exciter.....
(*a*) Volts.....
(*b*) Amperes.....

Power Input

(133) Volts.....
(134) Amperes per phase.....
(135) Power factor (from meter).....
(136) Exciter:.....
(*a*) Volts.....
(*b*) Amperes.....
(137) Efficiency of exciter (from builder's test).....
(138) Horsepower input to driving motor (calculated from voltmeter, ammeter, and power-factor meter).....hp.
(139) Horsepower input to driving motor by precision wattmeter..hp.
(140) Efficiency of driving motor (from builder's test).....hp.
(141) Net motor horsepower.....hp.
(142) Horsepower output for exciter.....hp.
(143) Net horsepower to drive exciter.....hp.
(144) Horsepower to drive compressor or blower.....hp.

TABLE 3 ADDITIONAL ITEMS APPLYING ONLY WHEN THE DRIVING ELEMENT IS A STEAM ENGINE

DESCRIPTION, DIMENSIONS, ETC., OF COMPRESSOR DRIVE

(47) Type of engine (simple or multiple expansion or uniflow).....
(48) Type of steam valves.....
(49) Auxiliaries (steam or electric drive).....
(50) Type and make of condenser equipment.....
(51) Rated capacity of condenser equipment.....
(52) Type of air pump, jacket pump, and reheater pump (direct or independently driven).....
(53) Type of governing apparatus.....

	1st Cyl.	2nd Cyl.	3rd Cyl.
(54) Diameter of steam cylinders.....in.			
(55) Stroke of pistons.....ft.			
(56) Clearance in terms of piston displacement, ...per cent			
(*c*) Clearance, crank end.....			
(*d*) Clearance, head end.....			
(57) Horsepower constant, steam cylinder:.....			
(*a*) Head end.....			
(*b*) Crank end.....			
(58) Area of steam-cyl. jacketed surface.....sq. ft.			
(59) Area of interior surface .....sq. ft.			
(60) Steam cylinder ratio (overall):			
(*a*) 1st cylinder to 2nd cylinder.....			
(*b*) 2nd cylinder to 3rd cylinder.....			

Average Pressures

(72) Pressure above atmosphere in steam pipe near throttle, by gage.....lb. per sq. in.
(*a*) Corresponding absolute pressure.....lb. per sq. in.
(*b*) Maximum pressure above atmosphere, steam-pipe diagram near throttle.....lb. per sq. in.
(*c*) Minimum pressure above atmosphere, steam-pipe diagram near throttle.....lb. per sq. in.

	1st cyl.	2nd cyl.	3rd cyl.
(73) Pressure in steam receiver by gage..... .....lb. per sq. in.			

(74) Pressure in exhaust pipe near engine by mercury column.....in. of mercury
(*a*) Corresponding absolute pressure.....lb. per sq. in.
(75) Pressure in jackets and reheater.....lb. per sq. in.

Average Temperatures

(102) Temperature of steam near throttle.....deg. fahr.
(103) Temperature of saturation at pressure near throttle..deg. fahr.
(104) Temperature of steam leaving steam receiver, if superheated.....deg. fahr.
(105) Temperature of steam in exhaust pipe as observed....deg. fahr.
(106) Temperature of saturated steam in exhaust pipe corresponding to pressure of exhaust in pipe.....deg. fahr.

Total Quantities

(109) Superheat, at throttle.....deg. fahr.
(110) Moisture in steam.....per cent
(111) Total steam and water consumed by engine as measured....lb.
(112) Total steam less water consumed.....lb.
(113) Correction factor conforming to conditions agreed upon.....lb.
(114) Equivalent total steam consumed, conforming to conditions..lb.

Unit Quantities

(123) Steam and water (or superheated steam) consumed per hour as measured.....lb.
(124) Steam less water (or superheated steam) consumed per hour..lb.
(125) Equivalent conforming to conditions consumed per hour.....lb.

Power Input

(172) Steam cylinder—Indicated horsepower developed, whole engine.....i.hp.

(173) High-pressure steam cylinder, crank end.....i.hp.
head end.....i.hp.
(174) Low-pressure steam cylinder, crank end.....i.hp.
head end.....i.hp.

Economy Results

(175) Steam less water (or superheated steam) consumed per i.hp-hr. (Item 124 ÷ Item 129).....lb.
(176) Equivalent steam consumed per i.hp-hr. (Item 125 ÷ Item 129).....lb.
(177) Steam less water (or superheated steam) consumed per ton of refrigeration at intake pressure and temperature (Item 112 ÷ Item 122a).....lb.
(178) Equivalent steam consumed per ton of refrigeration at intake pressure and temperature (Item 114 ÷ Item 122a).....lb.

TABLE 4 ADDITIONAL ITEMS APPLYING ONLY WHEN THE DRIVING ELEMENT IS AN INTERNAL-COMBUSTION ENGINE

(The items of this table will be developed upon the completion of the Test Code for Internal-Combustion Engines.)

B—ABSORPTION REFRIGERATING SYSTEMS

TABLE 5 DATA AND RESULTS OF TEST ON ABSORPTION REFRIGERATING SYSTEMS

General Information

(1) Date of test.....
(2) Location.....
(3) Owner.....
(4) Builder.....
(5) Test conducted by.....
(6) Object of test.....

Description, Dimensions, Etc.

(7) Type of condenser.....
(8) Area of condenser surface on refrigerant side.....sq. ft.
(9) Type of evaporator.....
(10) Area of evaporator surface on refrigerant side.....sq. ft.
(11) Type of water pumps..... No. 1 No. 2
(12) Rated capacity of water pumps.....
.....gal. per min. ....
(13) Type of brine pumps..... No. 1 No. 2 No. 3
(14) Rated capacity of brine pumps....gal. per min. ....
(15) Type of cooling tower.....
(16) Rated capacity of cooling tower.....
(17) Type of absorber.....
(18) Area of absorber surface on refrigerant side.....sq. ft.
(19) Type of generator.....
(20) Area of heating surface in generator.....sq. ft.
(21) Type of strong liquor pump.....
(22) Diameter of piston rod, liquor pump.....in.
(23) Stroke of liquor pump.....in.
(24) Piston displacement of liquor pump.....cu. ft.
(25) Type of rectifier.....
(26) Cooling surface in rectifier.....sq. ft.
(27) Type of exchanger.....
(28) Cooling surface in exchanger.....sq. ft.

General Data

(29) Composition of brine.....
(30) Specific gravity of brine at 68 deg. fahr. compared with water at 39.1 deg. fahr.....
(31) Specific heat of brine.....
(32) Specific gravity of liquid refrigerant as measured.....
(33) Concentration of strong liquor.....
(34) Concentration of weak liquor.....
(35) Quality of steam to generator.....
(36) Kind of cooling water used.....
(37) Specific gravity of cooling water.....
(38) Specific heat of cooling water.....

Test Data and Results

(39) Duration of tests.....hr.

Average Pressures

(40) Barometric pressure.....in. of mercury
(a) Corresponding absolute pressure.....in. of mercury
(41) Pressure in evaporator by gage.....lb. per sq. in.
(42) Steam pressure in generator, by gage.....lb. per sq. in.
(43) Pressure in absorber, by gage.....lb. per sq. in.
(44) Pressure in condenser, by gage.....lb. per sq. in.

Average Temperatures

(45) Engine-room temperature.....deg. fahr.
(46) Condenser-room temperature.....deg. fahr.
(47) Temperature of outside air.....deg. fahr.
(48) Temperature of wet bulb.....deg. fahr.
(49) Temperature of liquid from condensers.....deg. fahr.
(50) Temperature of liquid from liquid receivers.....deg. fahr.
(51) Temperature of liquid from liquid cooler.....deg. fahr.
(52) Temperature of liquid at measuring point.....deg. fahr.
(53) Temperature of water to cooling tower at measuring point.....deg. fahr.
(54) Temperature of water from cooling tower at measuring point.....deg. fahr.
(55) Temperature of brine, brine-cooler inlet at measuring point.....deg. fahr.
(56) Temperature of brine, brine-cooler outlet at measuring point.....deg. fahr.
(57) Temperature range through brine coolers by electric resistance thermometer.....deg. fahr.
(58) Temperature of ammonia vapor, inlet to rectifier.....deg. fahr.
(59) Temperature of ammonia vapor, outlet from rectifier.....deg. fahr.
(60) Temperature of weak liquor to weak-liquor cooler.....deg. fahr.
(61) Temperature of weak liquor from weak-liquor cooler.....deg. fahr.
(62) Temperature of water, inlet to weak-liquor cooler.....deg. fahr.
(63) Temperature of water, outlet from weak-liquor cooler.....deg. fahr.
(64) Temperature of weak liquor, inlet to absorber.....deg. fahr.
(65) Temperature of weak liquor, exit to generator.....deg. fahr.
(66) Temperature of strong liquor, inlet to exchanger.....deg. fahr.
(67) Temperature of strong liquor, outlet from exchanger.....deg. fahr.
(68) Temperature of condenser cooling water, inlet.....deg. fahr.
(69) Temperature of condenser cooling water, outlet.....deg. fahr.
(70) Temperature of steam to generator.....deg. fahr.
(71) Temperature of condensed steam from generator.....deg. fahr.

Total Quantities

(72) Liquid delivered to evaporator.....lb.
(73) Brine circulated.....lb.
(74) Strong liquor.....lb.
(75) Weak liquor.....lb.
(76) Steam condensed in generator.....lb.

Unit Quantities

(77) Liquid delivered to evaporator.....lb. per min.
(78) Brine circulated.....gal. per min.
(79) Cooling water supplied to condensers.....gal. per min.
(80) Cooling water supplied to absorber.....gal. per min.
(81) Cooling water supplied to rectifier.....gal. per min.
(82) Cooling water supplied to weak-liquor cooler.....gal. per min.

Refrigerating Output

(83) Available cooling effect (Q_e) (see Par. 21).....
(84) Tons of refrigeration produced (Item 83 ÷ 200).....
(85) Tons of refrigeration produced, brine method as a check:
(Item 78 × Item 57 × Item 30 × 8.33 × Item 31 ÷ 200).....

Economy Results

(86) Tons of refrigeration per pound steam used in generator.....

Generator

(87) Heat imparted by steam per min. (Q_s).....B.t.u.
(88) Heat imparted by steam per hour (Item 87 × 60).....B.t.u.
(89) Logarithmic mean temperature difference.....deg. fahr.
(90) Coefficient of heat transfer: K = (Item 88 ÷ Item 89 × Item 20).....B.t.u.

Condenser

(91) Heat removed per minute by condensing water (see Par. 30) (Item 68 — Item 69 × Item 79 × 8.33).....B.t.u.
(92) Heat removed as calculated from refrigerant condenser as a check (see Par. 30).....
(93) Heat removed per hour (Item 91 × 60).....B.t.u.
(94) Logarithmic mean temperature diff. (see Par. 31).....deg. fahr.
(95) Coefficient of heat transfer:
K = (Item 93 ÷ Item 94 × Item 8).....B.t.u.

Evaporator

(96) Heat removed per minute from brine.....B.t.u.
(97) Heat removed per hour (Item 96 × 60).....B.t.u.
(98) Logarithmic mean temperature diff. (see Par. 33).....deg. fahr.
(99) Coefficient of heat transfer:
K = (Item 97 ÷ Item 98 × Item 10).....

Absorber

(100) Heat removed by water per minute (Q_a).....B.t.u.
(101) Heat removed by water per hour, Item 100 × 60.....B.t.u.
(102) Logarithmic mean temperature diff.....deg. fahr.
(103) Coefficient of heat transfer:
K = (Item 101 ÷ Item 102 × Item 18).....B.t.u.

Strong Liquor Pump

(104) Indicated horsepower.....i.hp.
(105) Steam consumption.....lb. per hr.

Brine Pumps

(106) Gross or brake horsepower.....b.hp.
(107) Water horsepower (see Par. 34).....hp.
(108) Overall efficiency.....per cent

Water Pumps

(108) Gross or brake horsepower.....b.hp.
(110) Water horsepower.....hp.
(111) Overall efficiency.....per cent

Suggested Rules for the Care of Power Boilers

For Presentation at a Public Hearing at the A.S.M.E. Spring Meeting in Milwaukee, Wis.

IT IS the request of the Committee that these proposed rules be fully and freely discussed so that it may be possible for any one to suggest changes before the rules are brought to final form and presented to the Council for approval. Discussions should be mailed to C. W. Obert, Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be considered by the Boiler Code Committee.

A.S.M.E. Boiler Construction Code

Section VII

PREAMBLE

THESE rules, used in connection with steam boilers constructed in compliance with Section I of the A.S.M.E. Boiler Construction Code and for operation at a steam pressure exceeding 15 lb. per sq. in. above atmospheric pressure, will lead to safety in the use of steam boilers.

These rules are compiled to assist operators of steam boiler plants in maintaining their plants in as safe condition as possible, the subject of economy receiving only incidental consideration.

The difficulty in formulating a set of rules that may be applied to all sizes and types of plants is recognized; therefore these rules are suggestive only and it may be advisable to depart from them in certain cases.

DESCRIPTION OF SECTIONS

I *Rules for Routine Operation.* These rules are elementary and govern the proper procedure in performing the ordinary duties of operating and maintaining steam boilers.

II *Rules for Operating and Maintaining Boiler Appliances.* These rules are also elementary in character and are classified to give collectively all rules pertaining to any one boiler appliance, it being impracticable to include some of these rules in Section I.

III *Rules for Inspection.* These rules apply only to those who are responsible for the operation of boiler plants and must not be considered as applying to the state, municipal, or insurance companies' inspectors. Consideration should be given to the importance of continual inspection as compared with periodical inspection.

IV *Rules for the Prevention of Direct Causes of Boiler Failures.* These rules are intended as a guide and assistance to those who desire to make a more comprehensive study of the care of steam boilers in service. Their scope, including the entire boiler plant, is wider than that of Sections I and II. These rules are divided into two major subdivisions: Overpressure and Weakening of Structure. The rules on Overpressure deal with conditions which may cause boiler failure by subjecting the boiler to stresses greater than those for which it was designed. The rules on Weakening of Structure deal with conditions which may cause boiler failure by weakening the boiler structure to such an extent that it cannot withstand the stresses for which it was designed.

V *Partial Rules for Installation.* These rules are not complete. They treat with some conditions which are not encountered in the Rules for the Construction of Power Boilers.

Appendix—Feedwater Analysis, Treatment, and Control. The Appendix contains approved methods of investigating and reporting of analysis, treatment, and control of feedwater with the intent of standardizing methods and forms. It is not intended so much for the operating engineer as for those specializing in the chemistry of feedwater.

Respectfully submitted,

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Rules for the Care of Power Boilers

I—Rules for Routine Operation

PUTTING BOILERS IN SERVICE

Getting Up Steam

C-1. If the boiler is new or has been out of service for an extended period or has been opened for cleaning or repairs, examine the inside of the boiler and make sure that it is free from tools and foreign matter and that there is no one in the boiler; then close the manhole openings. In case of a new boiler, boil out for a few hours by the method given in Par. C-42.

C-2. See that the combustion chamber and gas passages are clean and in good repair, and that all clean-out doors in setting fit properly and are closed tight.

C-3. Operate both inlet damper and outlet damper and make sure that they are free and in good condition. Leave the inlet and outlet dampers open. Operate the stoker and draft fan to see that they are ready for service. Make sure that the grates are satisfactory and in place.

C-4. See that the blow-off valves, water column and water-glass drains, gage cocks, and feed valves are in good working condition and closed. Open a vent valve.

C-5. Fill the boiler to such a level that the rise in level due to the steam generation will bring the water level to its normal position when full working pressure and flow of the steam have been reached. Close feed connections. Where auxiliary feed connections are installed, they should be used in filling the boilers as a means of testing their condition. Open and close gage cocks and blow-down valves on water column, and water glass in order to make sure that these connections are free and clear.

C-6. See that the cock to steam pressure gage is open. Examine the safety valves as far as practicable to see that they are in working order.

C-7. Ease up on the stem of the main steam stop valve, slightly lifting the valve off the seat in order to make sure that the valve is not stuck.

C-8. If coal is used as fuel, cover the grate with a thin layer of coal and start a light fire with live coals from adjacent boilers, with wood or other light combustibles. Do not use any combustibles for igniting a coal fire in such a manner as to cause excessive smoke of possible flareback. Where pulverized coal, gas, or oil is used as fuel, make sure that outlet damper is open to create a light draft before introducing and igniting fuel.

C-9. If oil is used as fuel and the system is new or has been out of service for a considerable period, first clean and examine the strainers and remove, clean, and examine tips and burners. If compressed air is available, blow out the oil supply lines with air. Place and adjust burners and tips and work the air registers to see that they are in good working condition. Close individual burner throttle valves. Test the steam coils in the heater for oil leakage by keeping the maximum allowable head of oil on the heater, with the steam pressure shut off. Hold this head of oil on the heater in excess of 15 minutes. Next, unseat the steam valve on the coil with the drip valve wide open. Collect the condensate from the drip and examine for oil.

C-10. Remove any spilled oil about burners, fronts, and floor and see that there is no oil on the floor of the combustion chamber. Ventilate the boiler by opening draft gates and dampers.

C-11. If no steam is available for oil pump and burners, raise steam in boiler by wood fire. Remove any excess accumulation of water in the oil tank. See that oil pumps are warmed up ready for use and that relief valves are properly set. Open suction-line valves and pump oil to burners. If oil lines are equipped with air chambers, charge them with compressed air. Examine oil lines and equipment for leaks.

C-12. Light the center burner by holding a hand torch near and just under tip of burner then turning on the oil and stand well clear to avoid possible flareback. If the torch is snuffed out before the oil is lighted, shut off the oil and relight the torch. Always use the torch for lighting burners until the brickwork is intensely hot, and even then if all burners are out. Next light the adjacent burners, but be sure that there is an excess of draft before lighting additional burners. Do not allow the oil to impinge excessively on the brickwork or parts of the boiler.

C-13. After lighting the fire, maintain a light fire until the brickwork of the setting is dried out thoroughly. If the entire setting is new the drying out may require several days; if the lining of the combustion chamber only has been renewed, about 48 hours will be sufficient time for drying out for small settings. Larger ones will require a longer time. After the usual week-end shutdown, a light fire should be carried for about one hour. Only in extreme emergency should steam be raised in less than one-half hour, even with water-tube boilers.

C-14. After the water becomes heated, check the level of the water in the water glass with gage cocks and examine blow-off valves for leaks. After steam has escaped through the vent valves for a few minutes, close the valves.

C-15. After the brickwork is dried out and the boiler heated begin raising the steam pressure slowly, especially in internally fired boilers where the circulation is sluggish. Keep the water level in sight. When the steam pressure approaches the working pressure and before cutting the boiler into service blow the water down to the proper level, if necessary. Examine the boiler for leaks and test the safety valve or valves by hand, holding the valve or valves open for a short period to blow out possible accumulation of dirt or chips. On high-pressure boilers the safety valves should be popped well before the steam pressure approaches the working pressure.

Cutting In

C-16. Before cutting in a boiler, open and leave open until the boiler is on the line, all drains in the connections between the boiler and the main header, especially the open drains between the two stop valves. In general, in cutting in a boiler to a steam header already in service, the steam line between the boiler and the header is usually warmed up by backfeed through the drip line or by means of the by-pass valve, and the header valve fully opened and the boiler then allowed to cut itself in automatically with the non-return valve. In case a non-return valve is not used the boiler stop valve should, of course, be opened slowly when the pressure in the boiler and the steam line are approximately equal.

a. With two hand-operated stop valves, open slowly (to avoid water hammer), to full opening, the stop valve nearer the main header. When the pressure in the boiler is nearly equal to the pressure in the main header, open slowly, to full opening, the stop valve nearer the boiler. After opening each stop valve, stand by for a short period prepared to close the valve slowly in case there is any indication of water hammer.

b. With one hand-operated stop valve and one combined stop and check valve, when the hand-operated stop valve is nearer the main header, open it slowly and preferably only a small amount at first. Stand by for a short period to close the valve in case there is any indication of water hammer, then open the valve to full opening. When the pressure of the boiler is still 10 to 50 lb. below the pressure in the header, slowly back off the valve stem of the combined stop and check valve sufficiently from the check to provide full opening of the check valve. In order to insure that the check valve functions properly, always use it automatically for cutting in and cutting out boilers, provided that the main header is filled with steam at full pressure.

c. With one hand-operated stop valve and one automatic non-return check valve, open the hand-operated stop valve slowly when the pressure in the boiler is still 10 to 50 lb. below the pressure in the main header and stand by for a short period to close the valve slowly in case there is any indication of water hammer.

d. If steam is being raised on a boiler not connected to a common steam header, in general it would be more advisable to raise the steam pressure on the whole steam line at the same time, all drips being open.

e. After cutting in a boiler equipped with non-return valves, with two independent outlets, observe the steam pressure in the boiler to make sure that both valves open. If the non-return valve is a combined stop and check valve, operate the rising stem after the steam pressure in the boiler has reached its working pressure, in order to ascertain whether or not the valve has opened properly.

HANDLING BOILERS IN SERVICE

Firing

C-17. Aside from the standpoint of economy, maintain the fire as uniformly as possible in order to avoid excessive combustion, undesirable variations in temperature, and possible gas explosions. In the event of flareback or the snapping out of burners, where oil or gas is used as fuel, shut off the fuel supply and thoroughly ventilate the boiler before resuming firing.

Cleaning Fires

C-18. Clean the fires when necessary, but preferably at stated periods and when boilers are operating at low rating as at noon time and just before peak loads. Avoid holes in fire and excessive draft while burning out the fire. Clean fires as rapidly as possible to minimize cold air in the boiler. Do not fire too heavily immediately after cleaning. Do not pile hot ashes and clinkers against the boiler front; use care in quenching and remove ashes as soon as possible.

Banking Fires

C-19. When fires are banked and the furnace temperature is reduced, make sure that enough air is carried through the furnace and boiler to prevent the accumulation of combustible gases within the setting.

Water Level

C-20. The most important rule in the safe operation of boilers is to keep water in the boiler and as constantly at the proper level as conditions will permit. Never depend entirely upon automatic alarms or feedwater regulators, no matter how effective or valuable these devices may be.

C-21. The first duty on entering a boiler room is to ascertain whether the communications and valves between the boiler and the water glasses are free and open, especially when starting up in the morning, whether the fires have been banked over night or not, by blowing down the water columns and water glasses and noting the promptness of the return of the water to the glasses. Try the gage cocks also until sure of the water level. This should be done at the beginning of each shift and preferably before the relieved shift has gone off duty. It should also be done after replacing water glasses and more frequently when trouble is experienced with boiler compounds, foaming, priming, and other feedwater troubles that are apt to cause choking of the connections.

C-22. Have the water column well lighted and keep the glass clean. Do not allow steam to leak from the water column or its connections as this will cause the water glass to show a false water level. Keep the outlet end of the discharge pipes from the water column, water glasses, and gage cocks open and free from obstructions.

C-23. When the level of the water is not visible in the water glass, try the gage cocks to determine whether the level of the water is above or below the water glass. If the water level is below the water glass, stop the supply of air and fuel and close the dampers and ashpit doors unless you are in touch with the entire situation as to boiler-feedwater supply and positively certain that it is safer to continue steaming the boiler than to reduce the steaming rate. If found advisable not to stop the steaming rate of the boiler, determine the cause and remedy it immediately. If found advisable to stop the supply of fuel and air, do not change the feedwater supply, open the safety valves or change the steam outlet valves, or make any change that will cause a sudden change in the stresses acting on the boiler. In the case of hand-fired boilers, do not disturb the fire except to cover it with green coal or wet ashes; where stokers are used, stop the fuel feed and open the fire doors. After the fire is banked or out, close the feedwater valves. When the boiler is sufficiently cooled, close the fire doors and cut the boiler off the line. Determine the cause and remedy it before the boiler is again placed in service. Also examine the boiler for overheating.

C-24. When it becomes necessary to maintain an unreasonably high feedwater pressure, examine the feedwater lines for choking due to scale or other causes.

Foaming and Priming

C-25. If any unusual or serious foaming occurs, close the steam outlet valve long enough to determine the true level of the water in the water glass. If the level of the water in the glass is sufficiently high, blow down some of the water in the boiler and feed in fresh water. Use surface blow-off if installed. Repeat the alternate blowing down and feeding several times, and, if the foaming does not stop, bank the fire and continue the alternate blowing down and feeding. Test safety valve or valves and connections of pressure gage, water column, and water glass for any sticking or choking. Determine positively the cause of foaming and adopt measures to prevent its recurrence, as specified in Pars. C-203 to C-209.

Oil in Boiler

C-26. Watch carefully for any sign of oil in the feedwater heaters, water-glasses, and blowdowns. If a boiler becomes coated with oil or grease, shut down the boiler as soon as practicable and clean it thoroughly. If the amount of oil or grease is considerable, boil out the boiler in accordance with Par. C-42.

Feedwater Treatment

C-27. Execute carefully all instructions given for the treatment of feedwater if necessary in the particular plant. It is not advisable to experiment with "home-made" treatments or boiler compounds.

Blowing Down

C-28. Except where the amount and frequency of blowing down is determined by chemical analysis, blow down at least one full opening and closing of the blow-off valve every 24 hours. Blow down the boilers at a period in the day when the steam production is lowest. When boiler is equipped with both blow-off valve and cock or quick-opening valve in the same blow-off connection, always open the cock or quick-opening valve first and the blow-off valve second. In closing, always close the blow-off valve first and the cock or quick-opening valve second. Where a large amount of blowing down is necessary, open the cock or quick-opening valve first, until it is half-open and leave in that position until the water is lowered about $\frac{1}{2}$ in. in the water glass. Then open wide all valves until the blowing down is completed. See that the cock or valve shuts tight and remains tight. Repair all leaky blow-off valves or cocks as soon as practicable. Use surface blow-off if installed until the undesirable conditions for which it is employed are corrected.

C-29. Where the water glass is not in view of the operator blowing down a boiler, another operator should be stationed where he can see the water glass and signal to the operator blowing down the boiler.

Leaks

C-30. When small leaks occur, locate their source and repair them as soon as the boiler can be removed from service. If a serious leak occurs such as a leak along the longitudinal seams, or near flange of drum heads, shut down the boiler immediately by gradually reducing the steam pressure and have the boiler examined by an authorized inspector.

In case of tube failure shut off air supply, keep outlet damper open, check fire and shut boiler stop valve. Maintain feedwater supply, if possible to do so, without drawing too heavily upon the supply to other boilers. Shut off feedwater supply when brickwork has cooled sufficiently to prevent injury to boilers by overheating.

Repairs

C-31. Many casualties have resulted from the practice of repairing boilers, pipe lines and attachments under pressure; such practice

should not be permitted except under the supervision of a competent and responsible person.

Removal of Soot and Ashes

C-32. Keep tubes reasonably free from soot. When a lance or soot blower is used, drain the steam or air supply connections so that the steam or air is practically dry. After the boiler has been cooled, brush or scrape any hardened soot or deposit from the tubes.

C-33. Remove ashes frequently and do not permit the accumulation of any large amount of ashes in the ashpit, boiler flues, or base of chimney. Do not pile ashes against the boiler front and when wetting down ashes, make sure that no water is thrown upon hot castings. To avoid being scalded, stand well back from hot ashes or refuse while spraying water on them. Do not leave ashes banked about blow-off pipes as a protection.

C-34. When ashes are removed by a suction system, see that the explosion door on the storage hopper is maintained free and in condition. Where steam-jet ash conveyors are used, see that all operators are warned against the water which may collect upon the top of the ashes in the hopper and which may flow suddenly from the gate when the ashes are being removed. When necessary to bar through the gate to release clogged opening, the operator should stand sufficiently aside to avoid being burned by the hot ashes or water.

HANDLING BOILERS OUT OF SERVICE

Cutting Out

C-35. Stop the supply of fuel, burn out the fuel in the furnace, and cool off the setting and boiler as slowly as is consistent with operating conditions.

After the boiler ceases to require feedwater and the non-return check valve, if any, on the steam outlet has closed, close the feedwater valves and the main steam stop valve. Where both one hand-operated stop valve and one combined stop-and-check valve are used, screw down the stem of the combined stop-and-check valve to hold the valve disk on the seat. Where two stop valves are used, open the drain between the stop valves and see that it is clear. When possible, dust off tubes before fire has died out.

Emptying

C-36. Allow the setting to cool slowly, particularly where there is much sediment in the boiler. After the setting has been cooled and there is no pressure on the boiler, open the vent to prevent the formation of a vacuum and empty the boiler. When it is not practicable to empty a boiler at atmospheric pressure, blow it down at as low a pressure as is consistent with operating conditions. When the boiler to be emptied is set in a battery of two or more boilers, make sure that the blow-off valves that are opened are on the boiler that is to be emptied. As soon as the boiler is emptied, close the blow-off valves, remove the manhole plates, and, when necessary, the covers of other openings.

Cleaning

C-37. Before any person enters the drums or shell of the boiler, make sure that these parts of the boiler have been properly ventilated and that there is no inflammable gas present.

C-38. Before entering the drums or shell of a boiler, see that the blow-off valves, the main stop valve, the feedwater valves, and other valves are closed. Use some reliable method of safeguarding any one entering the shell or drum.

It is recommended that when the blow-off valves of a boiler being cleaned are connected into a common header, the blow-off valves of all other boilers be properly safeguarded against opening into the boiler being cleaned.

When electric extension cords are used when entering a boiler, the cord should not only be well insulated but designed to withstand mechanical injury and maintained in good condition. The lamps should be provided with suitable guards.

C-39. Examine the boiler to determine how often it should be washed.

C-40. Use hose with considerable force or hand tools if necessary to remove scale. Disconnect the blow-off line close to the boiler and run the water to waste, or when practical provide a screen which can be inserted in the blow-off hole. Wash the tubes of horizontal-return tubular boilers from below as well as from above.

See that the water does not come in contact with the brickwork of the combustion chamber, or if this cannot be avoided, see that the brickwork is dried out carefully when firing up.

C-41. After washing the boiler, pass a light inside and see that the cleaning has been thorough and that no tools are left inside.

C-42. Where a new boiler is to be placed into service for the first time, it may be cleaned by boiling out with a mixture of soda ash and caustic soda. Fill the boiler with water to about the middle line of the water glass and add one part by weight of soda ash and one part caustic soda at a rate of 20 lb. per 100 hp. capacity. Dissolve the chemicals thoroughly before introducing into the water. Close the boiler and start a light fire, sufficient to carry 5 lb. pressure in the boiler. Continue boiling two or three days. Empty the boiler and then wash thoroughly with fresh water.

C-43. When cleaning scale from tubes with mechanical hammer or cleaner, follow the instructions given in Par. C-270.

Laying Up

C-44. When laying up a boiler for an extended period of time, follow the instructions given in Pars. C-244 to C-248.

II—Rules for Operating and Maintaining Boiler Appliances

Steam Pressure Gage

C-45. Compare boiler steam gages frequently. Test at times of external inspection, when the boiler is placed in service after periods of shutdown for internal inspection or repairs and after an extended period of shutdown. When the safety valve pops, note the reading of the gage and, if the reading is not in agreement with the stipulated popping pressure nor with gages on adjacent boilers operating under the same pressure, test the gage. See that the gages are tested when trouble is experienced with boiler compounds, foaming, priming, and other feedwater troubles that are apt to cause choking of the gage connections.

C-46. A steam gage is considered tested when it has been compared and made to agree with a dead-weight testing device, or a test gage which has been so tested. When compensation for water-leg has been made, make an equivalent allowance in the reading of the test gage or dead-weight testing device. Use only a reliable gage for a test gage and use it exclusively for testing gages in service.

C-47. Before testing a steam pressure gage, disconnect it at the gage union and clear the piping, cock, and siphon by blowing through unless this can be done by opening a plug or valve connection. After blowing through, reconnect the gage. Do not admit steam directly into the gage and be sure at all times that the siphon is filled with water. If steam has entered the gage, it must be retested.

C-48. Keep the gages well lighted at all times and the dials and glass covers clean. See that the glass cover is maintained tight and whenever the glass is broken that it is replaced as soon as possible.

C-49. When a boiler steam gage, not in use, is likely to be subjected to freezing temperatures, drain the connections and gage.

Water Glass

C-50. Keep the communications and valves between the boiler and the water column and water glass free and clear and test by blowing down the water column and water glass, noting the promptness of the return of the water to the water column and glass, and trying the gage cocks until sure of the water level.

C-51. All water columns and water glasses shall be tested by the water tender, or operator directly responsible for the level of the water in the boiler, at the beginning of each shift and preferably before the relieved shift has gone off duty.

By shift is meant a person or group of persons who relieve a person or group of persons in rotation in standing watch or operating a steam generating plant for an allotted time. It is synonymous with *watch, vigil,* or *tour of duty.*

C-52. Test water glasses after replacing. Test all water glasses on a boiler when the boiler is placed in service, and when trouble is experienced with boiler compounds, foaming, priming, or other feedwater troubles that are apt to cause choking of the connections.

C-53. Water glasses and their connections shall be kept free

from leaks and no connections allowing a flow of water or steam from the piping between the water column or water glass and the boiler shall be made, as such leaks or flow of water or steam will cause a false indication of the water level in the boiler.

C-54. The outlet end of the discharge pipes from water columns, water glasses, and gage cocks shall be kept open and in sight or hearing of operator while blowing down.

C-55. Keep water glasses well lighted and clean. When they need cleaning, replace them with clean glasses. Attempts to clean glasses in place lead to possible cracking of the glass or choking from pieces of cloth or waste.

C-56. When a water glass has broken, remove the broken pieces and slowly open the valves to blow out any remaining pieces. Before inserting the new glass, see that the drain is open and that the glass is of the exact length required and that the connections are in line. Insert the glass with packing and set up the stuffing-box nuts, taking care not to set them up too tight. Then warm the glass by opening the top valve slightly and let a small current of steam flow through the glass. Close the drain cock after the glass is sufficiently warmed, open the bottom valve slightly and when the level of the water in the glass has become stable, open the bottom valve wide and then open the top valve wide.

C-57. Unless the water glass is provided with a guard to protect the operator while replacing water glasses on boilers under pressure, or unless the operator wears a mask, the valves shall be operated only by remote control. A suitable water-glass guard may be made in the form of an inverted cone of No. 22 black iron wire screen of $^1/_8$ in. mesh.

Feedwater Regulators

C-58. If feedwater regulators are used, see that they are maintained in good working condition, but do not place complete dependence on the regulators to maintain the proper level of water in the boiler.

Fusible Plugs

C-59. If fusible plugs are used, see that they are kept in good condition and that they are not used for more than one year as provided for in Par. A-19 of the Power Boiler Section of the Code. When the boiler is open, scrape clean and bright the exposed surfaces of the fusible metal as well as the surface of the boiler near the plugs. If the fusible metal does not appear sound, renew the plug. Never refill a plug with anything but new metal of a quality specified in Par. A-19 of the Power Boiler Section of the Code.

Safety Valves

C-60. Keep all safety valves free and in working order.

C-61. Test the valves in accordance with the instructions given for the particular plant. Test the safety valves by gently raising the valve off the seat by hand or, when practicable, test the valves daily by raising the steam pressure to the popping pressure of the safety valve. Small chains or wires attached to the levers of pop safety valves and extended over pulleys to other parts of the boiler room may be used. If the valve sticks, do not try to release it by hammering; drop the pressure in the boiler and clean the valve seat or correct any other defect that may be found. When an additional safety valve is installed on a boiler in excess of the capacity required by the Rules for the Construction of Power Boilers and the capacity of that valve is equal to the capacity of the faulty safety valve, the boiler may remain in operation until it can be conveniently taken out of service.

C-62. Do not try to stop leakage by tightening the spring or by blocking it in any manner whatsoever. When a safety valve leaks at a pressure less than that at which it is set to close, repair or replace it as soon as practicable.

C-63. Whenever the safety valve pops, observe the pressure indicated by the boiler gage and, if the noted pressure varies more than 5 lb. from the stipulated popping pressure, test the gage. If the gage is found correct, adjust the safety valve. Where the working pressure is in excess of 250 lb. per sq. in., the allowable variation shall be 2 per cent of the working pressure.

C-64. Do not allow the setting or adjustment of safety valves by any one but a competent person. Any setting or adjusting of the blowback ring or any device to regulate this feature, shall be done only by a competent mechanic familiar with the construction and operation of safety valves. Test the safety valve after any setting or adjusting of the spring or blowback ring. Do not have the water in the boiler above the highest gage cock when setting or adjusting the valve. When the spring becomes weak and must be screwed down to secure the stipulated popping pressure, make sure that the spring is not screwed down so far that there is a restriction of the proper amount of the opening of the valve as required in Pars. P-282 and P-284 of the Power Boiler Section of the Code.

C-65. Safety valves shall not be opened to reduce steam pressure in the case of low water.

C-66. Never set the popping point of a safety valve above the pressure authorized for the boiler. When there is more than one safety valve on a boiler, the setting of the popping point of the safety valves shall be in accordance with Par. P-271 of the Power Boiler Section of the Code. If the popping pressure of a safety valve is to be more than 10 per cent above or below the pressure for which the spring is designed, replace the spring with another spring designed for the proper pressure.

C-67. Where boilers are connected into a common steam header and operate under the same working pressure and some of the boilers have allowable working pressures greater than others, never set a safety valve to pop at a pressure greater than that allowed on the weakest boiler unless the lower-pressure boilers are equipped with non-return check valves and sufficient safety-valve capacity is added to the lower-pressure boilers or to the low-pressure header to take care of the capacity of the higher-pressure boilers.

C-68. Care shall be exercised to prevent the accumulation of scale, dirt or other foreign matter from collecting between the coils of the spring of the safety valve.

C-69. Keep the drain in the escape pipe open. If the safety valve pops when the operator is in a favorable position, he should observe the drain in the escape pipe in order to determine that the drain is unobstructed. When running a wire in the drain hole in the escape pipe to ascertain if it is clear, be careful that the wire does not move scale that may fall over the drain opening when the wire is removed.

C-70. Maintain the proper tension on all supports and anchors to which the escape pipe is attached and examine them at least every six months.

C-71. When making a hydrostatic test, remove the safety valves and blank the opening or clamp the valve disk securely to the seat. Also remove the water column floats, if necessary. Make sure that the safety valve is placed in good working condition after the hydrostatic test has been made.

Blow-Off Equipment

C-72. Maintain blow-off valves and cocks in good working condition and repair leaking blow-off valves as soon as practicable. See that they are in good working condition before putting a boiler in service and examine them periodically, when boiler is washed out and at times of internal inspection. Maintain in good condition the pipe and fittings between the blow-off valve and the boiler together with their insulation and inspect them periodically, at times of internal inspection and particularly when the boiler is washed out. If the discharge end of the blow-off line is visible, watch it for the purpose of detecting leaky blow-off valves.

C-73. Open and close blow-off valves or cocks carefully and slowly, and in closing the blow-off valve see that it is closed tight.

C-74. Where a large amount of blowing down is necessary, open one valve wide and the second valve until it is half open and leave it in that position until the water is lowered about $^1/_2$ in. in the water glass; then open the second valve wide until the blowing down is completed.

C-75. When an operator is blowing down a boiler and cannot see the water glass, station another operator to watch the water glass and to signal the operator blowing down the boiler. Never permit one operator to blow down more than one boiler at a time and, when a boiler to be emptied is set in a battery of two or more boilers, make sure that the blow-off valves opened are on the boiler to be emptied. When blowing down a boiler do not fail to give entire attention to that duty, and perform no other duty until the blow-off valves have been closed.

C-76. Study carefully the conditions of the particular plant in

order to determine the amount and frequency of blowing down; determine it by chemical analysis if possible. The amount and frequency of blowing down depends upon the number of hours a day that the boiler is in service, the rate at which it operates, and the kind of feedwater used (see Pars. C-202 to C-209). Except where the amount and frequency of blowing down are determined by chemical analysis, blow down at least one full opening and closing of the blow-off valve every 24 hours.

C-77. Blow down the boiler, if necessary, just before cutting in. When a boiler is in service, see that the blowing down is done at a time when the generation of steam is lowest. If any unusual or serious foaming occurs, check the fuel and air supply and close the steam outlet long enough to determine the true level of the water in the water glass. If the level of the water in the glass is sufficiently high alternately blow down some of the water in the boiler and feed in fresh water several times. Use surface blow-off if installed. If the foaming does not then stop, bank the fire and continue the alternate blowing down and feeding.

C-78. Allow the setting to cool slowly, particularly where there is much sediment in the boiler. After the setting has been cooled and there is no pressure on the boiler, open the vent and empty the boiler. When it is not practicable to empty a boiler at atmospheric pressure, blow it down at as low a pressure as is consistent with operating conditions. When the boiler to be emptied is set in a battery of two or more boilers, make sure that the blow-off valves that are opened are on the boiler that is to be emptied. As soon as the boiler is emptied, close the blow-off valves, remove the manhole plates, and, when necessary, the covers of other openings.

C-79. Before entering the drums or shell of a boiler, see that the blow-off valves, the main stop valve, the feedwater valves, and other valves are closed. Use some reliable method of safeguarding any one entering the shell or drum.

It is recommended that when the blow-off valves of a boiler being cleaned are connected into a common header, the blow-off valves of all other boilers be properly safeguarded against opening into the boiler being cleaned.

When electric extension cords are used when entering a boiler, the cord should not only be well insulated but designed to withstand mechanical injury and maintained in good condition. The lamps should be provided with suitable guards.

C-80. Use hose with considerable force or hand tools if necessary, to remove scale. Disconnect the blow-off line close to the boiler and run the water to waste, or when practical provide a screen which can be inserted in the blow-off hole. Wash the tubes of horizontal-return tubular boilers from below as well as from above.

See that the water does not come in contact with the brickwork of the combustion chamber, or if this cannot be avoided, see that the brickwork is dried out carefully when firing up.

Dampers

C-81. Maintain all dampers in good working order and inspect them before starting a boiler, periodically when boiler is in service, and at times of internal inspection.

C-82. If damper regulators or draft-control devices are used, see that they are kept in good working condition and inspected before starting a boiler, periodically when boiler is in service, and at times of internal and external inspections. Be alert to detect any unusual conditions which may affect the safety of the structure. Such devices do not relieve the operator of responsibility.

C-83. If coal is used as fuel, cover the grate with a thin layer of coal and start a light fire with live coals from adjacent boilers, with wood, or other light combustibles. Do not use any combustibles for igniting a coal fire in such a manner as to cause excessive smoke or possible flareback. Where pulverized coal, gas, or oil is used as fuel, make sure that outlet damper is open to create a light draft before introducing and igniting fuel.

C-84. Under normal operation avoid an excessive amount of air but do not decrease the air to a condition that will cause a dangerous amount of incomplete combustion or objectionable pressure in the combustion chamber. In the case of fluid fuels, when increasing or decreasing the rate of firing, increase the air supply before increasing the fuel supply and decrease the fuel supply before decreasing the air supply.

C-85. Avoid excessive draft or pressure while cleaning fires.

Banking Fires

C-86. When fires are banked and the furnace temperature is reduced, make sure that enough air is carried through the furnace and boiler to prevent the accumulation of combustible gases within the setting.

C-87. When the level of the water is not visible in the water glass, try the gage cocks to determine whether the level of the water is above or below the water glass. If the water level is below the water glass, stop the supply of air and fuel and close the dampers and ashpit doors unless you are in touch with the entire situation as to boiler-feedwater supply and positively certain that it is safer to continue steaming the boiler than to reduce the steaming rate. If found advisable not to stop the steaming rate of the boiler, determine the cause and remedy it immediately. If found advisable to stop the supply of fuel and air, do not change the feedwater supply, open the safety valves or change the steam outlet valves, or make any adjustment that will cause a sudden change in the stresses acting on the boiler. In the case of hand-fired boilers, do not disturb the fire except to cover it with green coal or wet ashes; where stokers are used, stop the fuel feed and open the fire doors. After the fire is banked or out, close the feedwater valves. When the boiler is sufficiently cooled, close the fire doors and cut the boiler off the line. Determine the cause and remedy it before the boiler is again placed in service. Also examine the boiler for overheating.

C-88. In case of tube failure shut off air supply, keep outlet damper open, check fire and shut boiler stop valve. Maintain the feedwater supply, if possible to do so, without drawing too heavily upon the supply to other boilers. Shut off the feedwater supply when the brickwork has cooled sufficiently to prevent injury to the boilers by overheating.

C-89. In the event of flareback or the snapping out of burners where oil or gas is used, shut off the fuel supply and thoroughly ventilate the boiler before resuming firing.

C-90. Keep the draft on while blowing soot from the tubes.

C-91. When cutting out a boiler, stop the supply of fuel, burn out the fuel in the furnace, and adjust the dampers to cool off the setting and boiler as slowly as is consistent with operating conditions. When possible, dust off tubes before fire has died out.

III—Rules for Inspection

Preliminary

C-92. All power boilers should be given one internal and two external inspections per year by the state or municipal inspectors having jurisdiction or by the inspectors of the insurance company carrying the risk. These inspectors are hereinafter termed authorized inspectors.

C-93. Similar inspections should be made by the person responsible for the boiler plant as a whole or his duly authorized representative who is hereinafter termed the "plant inspector." Such inspections shall be supplementary to and in no wise considered as supplanting or superseding the inspections made by authorized inspectors. Such inspections shall be made in accordance with the following rules:

C-94. A record of each inspection shall be kept in a uniform manner so that any change of condition can be definitely compared, especially with reference to thickness of scale, corrosion, cracks, and other unusual conditions.

C-95. Between periodical inspections by authorized inspectors, the plant inspector shall closely observe the operation and condition of the boilers and shall report immediately to the proper authorities any serious defects, doubtful conditions, or unusual occurrences.

C-96. An external inspection shall comprehend the superficial examination of the boiler, its appurtenances and connections, and does not necessarily require that the boiler be off the line. It is a form of examination to check up care and management mainly.

C-97. The internal inspection of the boiler shall be a comprehensive and thorough examination in every detail, embracing particularly the determination of the suitability of the boiler for pressure carried, strength of its parts, possible deterioration in service, and advisability of its continuance under the pressure carried previous to inspection.

C-98. No particular preparations shall be necessary for an ex-

ternal inspection other than giving the plant inspector convenient access to the boiler and its connections.

C-99. The internal inspection shall call for somewhat extensive preparation, mainly the proper cooling and opening up the boiler together with a thorough cleaning of the boiler, including setting.

C-100. The walls, baffles, tubes, and shell shall be thoroughly swept down and the ash and soot removed to give the plant inspector opportunity to examine the parts closely and to eliminate danger from hot contact.

C-101. Where steam soot blowers are used, the tubes shall be well dusted and cleaned before the blowing operation has commenced.

C-102. When boiler and setting are sufficiently cooled, the blow-off valve shall be opened and the water removed. Then the manhole and handhole covers shall be removed to allow circulation of air through the boiler.

C-103. The inside of shell, drums, and tubes shall then be washed down thoroughly to remove mud, loose scale, or similar deposits. The washing operation shall be conducted from above as far as possible to carry the material downward to blow-off or lower handholes.

C-104. Use hose with considerable force or hand tools if necessary to remove scale. Disconnect the blow-off line close to the boiler and run the water to waste, or, when practicable, provide a screen which can be inserted in the blow-off hole. Wash the tubes of horizontal-return tubular boilers from below as well as from above.

See that the water does not come in contact with the brickwork of the combustion chamber, or if this cannot be avoided, see that the brickwork is dried out carefully when firing up.

C-105. Before entering the drums or shell of a boiler, see that the blow-off valves, the main stop valve, the feedwater valves, and other valves are closed. Use some reliable method of safeguarding any one entering the shell or drum.

It is recommended that when the blow-off valves of a boiler being cleaned are connected into a common header, the blow-off valves of all other boilers be properly safeguarded against opening into the boiler being cleaned.

When electric extension cords are used for entering a boiler, the cord should not only be well insulated but designed to withstand mechanical injury and maintained in good condition. The lamps should be provided with suitable guards.

C-106. The plant inspector shall have available the data on the boiler, dimensions, age, particulars as to previous defects noted, if any, and shall watch for any indication of decrease in the pressure-carrying capacity of the boiler and report any such findings to his immediate superiors.

External Inspection

C-107. The plant inspector shall examine the boiler for level, noting whether or not there has been any tendency to settlement, especially the transverse level of the top tubes in horizontal-return tubular boilers. He shall see that proper provision is made for expansion.

C-108. Examination shall then be made of the feed connection to see that it is clear and in good working condition.

C-109. Examination shall be made for evidences of corrosion on the exterior of shell from rain coming down the stack, or from leaking roofs, valves, or pipes.

C-110. Inspection shall be made to see if there is any leakage of flame on dry sheets, particularly at the back arch of return-tubular boilers, which should be entirely clear of the rear tube sheet with sheet metal or asbestos rope covering the gap. Tie rods and buck stays shall be examined for condition and possible shifting from place.

C-111. The plant inspector shall note the proximity of overhead shafts or any machinery which might drop down on or strike the boiler in case of accident.

C-112. The plant inspector shall note the presence of lumber or other material piled on boiler or setting for purposes of drying or storage and which may endanger the setting or the safety and accessibility of the apparatus. The practice of drying or storing materials on top of boiler settings should not be allowed.

C-113. A careful examination shall be made of the safety valve, its connection to the boiler, its escape pipe, its drip, and supports.

Test the valves in accordance with the instructions given for the particular plant. Test the safety valves by gently raising the valve off the seat by hand, or, when practicable, test the valves daily by raising the steam pressure to the popping pressure of the safety valve. Small chains or wires attached to the levers of pop safety valves and extended over pulleys to other parts of the boiler room may be used. If the valve sticks, do not try to release it by hammering; drop the pressure in the boiler and clean the valve seat or correct any other defect that may be found. When an additional safety valve is installed on a boiler in excess of the capacity required by the Rules for the Construction of Power Boilers and the capacity of that valve is equal to the capacity of the faulty safety valve, the boiler may remain in operation until it can be conveniently taken out of service.

C-114. The water glass, gage cocks, water-column connections, and blow-offs shall be tested to see if the connections are free. Boiler pressure gages and master gages shall be checked with other reliable gages in the same system. It should also be done after replacing water glasses and more frequently when trouble is experienced with boiler compounds, foaming, priming, and other feedwater troubles that are apt to cause choking of the connections.

Internal Inspection

C-115. The plant inspector shall enter the drums of the boiler to make personal examination of conditions, but before entering he shall first make sure that they have been properly ventilated and that there is no inflammable gas present.

C-116. Before entering the shell or drum the plant inspector shall see that the blow-off valve, the main steam valve, feedwater valves, and other valves are closed. Use some reliable method of safeguarding any one inside the boiler.

C-117. Careful examination of the interior of the boiler shall be made for cracks, pitting, corrosion, scale, and thin places in the shell. The upper half of drums in the steam space shall be examined particularly for signs of grease and oil.

C-118. The interior of the tubes should be examined for scale and deposits and the space between the tubes in the case of a return-tubular boiler made visible by lowering candle or small light between them for the purpose of making sure that there is no restriction of the circulation.

C-119. The location of the feed discharge and condition of the trough under it shall be noted. Dry pipes shall be examined to see that their openings and perforations are free from deposits. All interior fittings shall be examined for loose connections.

C-120. The interior face of the riveted joints shall be examined for condition of riveting, thinness of metal, corrosion, cracks, etc. The plant inspector shall note any wasting away and cracking of stays and braces. Particular examination shall be made of any welded stays or braces.

C-121. If fusible plugs are used, see that they are kept in good condition and that they are not used for more than one year as provided for in Par. A-19 of the Power Boiler Section of the Code. When the boiler is open, scrape clean and bright the exposed surfaces of the fusible metal as well as the surface of the boiler near the plugs. If the fusible metal does not appear sound, renew the plug. Never refill a plug with anything but new metal of a quality specified in Par. A-19 of the Power Boiler Section of the Code.

Furnace and Parts Exposed to Fire

C-122. The plant inspector shall go into the furnace for the examination of the exterior of the tubes, shell, brickwork, and baffles.

C-123. Where soot blowers are used the inspector should examine them and also examine the boiler tubes for injury due to impingement of steam.

C-124. The plant inspector shall examine the setting for cracks, settlement, and loose brick which may lean against the boiler. Where brickwork is used as insulation of steel supporting members it shall be examined to see that it is in good condition and that the air space, if any, is maintained. The furnace lining shall be examined for spalling, cracking, and settlement. In vertical water-tube boilers, the bridge walls shall be inspected to see that the mud drum is properly protected. The plant inspector shall examine baffle and check walls particularly for holes which may permit flaming through.

C-125. The blow-off connection should be examined carefully for corrosion and weakness where it connects with the boiler. The protective cover of brick or tile should be intact and not interfere in any way with the expansion of the boiler or pipe.

C-126. Particular attention shall be given the tube ends and tube sheets in the case of horizontal-return tubular boilers. The plant inspector shall note any corrosion of the sheets, signs of leaking tubes, excessive thinning of the tubes from repeated rollings, and the condition of tube ends of circulating tubes and mud-drum nipples of water-tube boilers.

C-127. The plant inspector shall note any tendency to corrosion from leakage of manhole and handholes under tubes in tube sheets of return-tubular boilers.

Appurtenances

C-128. An examination of the condition of the main header and its connections to the boiler shall be made to ascertain that it is properly supported, that due allowance is made for expansion without throwing strains on the boiler, and that the non-return stop valves are in good working condition and so placed that there is no pocket in the connection to hold water unless properly drained.

C-129. The plant inspector shall note the position of the steam gage and gage cocks, ascertain that the pipes leading to the water column and water glass are level, and by leveling across the top row of tubes or from the position of the fusible plug check the position of the water glass.

C-130. Check the pipe line and all exterior supports to see that the proper tension and alignment are maintained. Where boiler foundations are independent of building foundations, joints on the steam and feed connections shall be disconnected once a year or other reliable means shall be employed to check possible settlings.

Care and Management

C-131. The plant inspector shall note particularly any evidences of carelessness in the care and management of the boiler and its appurtenances.

C-132. The plant inspector shall recommend immediate remedy of any unsafe conditions or undesirable practices he may uncover and shall report promptly and fully on the results of his inspection to his immediate superiors.

C-133. The plant inspector should be furnished a copy of all reports of inspections made by authorized inspectors and see that all recommendations in such reports are promptly and carefully carried to completion.

IV—Rules for the Prevention of Direct Causes of Boiler Failures

OVERPRESSURE

INDICATORS

Steam Pressure Gages

C-134. A steam gage shall be considered tested when it has been compared and made to agree with a dead-weight testing device, or a test gage which has been so tested.

C-135. In order to insure an accurate basis for comparison, the test gage shall be a reliable gage that is used exclusively for testing gages in service and one that is tested and maintained in agreement with a dead-weight testing device. When compensation for the waterleg has been made, an equivalent allowance shall be made in the reading of the test gage or dead-weight testing device.

C-136. Compare the boiler steam gages frequently. Test at times of external inspection, when the boiler is placed in service after periods of shutdown for internal inspection or repairs, and after an extended period of shutdown. When the safety valve pops, note the reading of the gage and, if the reading is not in agreement with the stipulated popping pressure nor with the gages on adjacent boilers operating under the same pressure, test the gage. See the gages are tested when trouble is experienced with boiler compounds, foaming, priming, and other feedwater troubles that are apt to cause choking of the gage connections.

C-137. Before testing a steam pressure gage, disconnect it at the gage union and clear the piping, cock, and siphon by blowing through. After blowing through, reconnect the gage. Do not admit steam directly into the gage and be sure that at all times the siphon is filled with water. If steam has entered the gage, it must be retested.

C-138. Keep the gages well lighted at all times and the dials and glass covers clean. See that the glass cover is maintained tight and, whenever the glass is broken, that it is replaced as soon as possible.

C-139. When a boiler steam gage, not in use, is likely to be subjected to freezing temperatures, drain the connections and gage.

C-140. A master steam gage is an auxiliary gage attached to the main header indicating the composite boiler pressure of the whole battery; it is used in the general operation of the plant mainly as a matter of convenience. Master steam gages shall be tested when they are not in reasonable agreement with other reliable steam gages about the plant.

[The remainder of this Code, comprising, the rest of Section IV—Rules for Prevention of Direct Causes of Boiler Failures, Section V—Partial Rules for Installation, and Appendix, will appear in a later issue of MECHANICAL ENGINEERING. Complete pamphlet copies of the Suggested Rules for examination and study in advance of the Public Hearing in Milwaukee, Wis., on May 18th, may be obtained upon application to the Secretary of the Boiler Code Committee, 29 West 39th Street, New York, N. Y.—EDITOR.]

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society, for approval, after which it is issued to the inquirer and simultaneously published in MECHANICAL ENGINEERING.

Below are given interpretations of the Committee in Cases Nos. 472, 473, and 477–486 inclusive, as formulated at the meetings of January 14 and February 20, 1925, all having been approved by the Council. In accordance with established practice, names of inquirers have been omitted.

CASE NO. 472

Inquiry: What specifications in the Boiler Code are applicable to round and square tubing material when used for the construction of headers for boilers?

Reply: It is the opinion of the Committee that if the material will conform to either of the specifications for boiler tubes or for pipe materials contained in the Material Specifications Section of the Code, the requirements of Par. P-9 will be met, except that in the case of sinuous headers the flattening, crushing, or bending tests need not be made, the work done on the material in forming the sinuous header taking the place of these tests.

CASE NO. 473

Inquiry: Is it permissible, under the requirements of the Boiler Code, to acetylene weld the vertical seam of the firebox of a vertical-tubular boiler, using a butt-welded joint with the staybolts passing through the center line of the weld, it being understood that the furnace sheet is staybolted to support the full load thereon?

Reply: It is the opinion of the Committee that if the stress on the furnace sheet due to the steam pressure is fully supported by staybolting, the welding of the vertical seam in the firebox of a vertical-tubular boiler is permissible under Par. P-186 of the Code. The welded seam shall be located between two rows of staybolts.

CASE NO. 477

Inquiry: Is the girth joint where the shell is joined to the head of a water-tube boiler drum considered, under the terms of Par. P-184d, as a circumferential joint? Also, can this distance be measured from the center of the rivet hole to the calking edge of the plate before calking?

Reply: It is the opinion of the Committee that the rule in Par. P-184d applies to boilers where the stress on the heads is relieved or partly supported by tubes or through stays. It is the further opinion of the Committee that for other constructions the requirements of Par. P-183, which relates to longitudinal joints, should apply to circumferential joints including head joints.

CASE NO. 478 (In the hands of the Committee)

CASE NO. 479

Inquiry: In calculating the staying of heads of welded steel heating boilers, is it permissible to exempt the 3-in. strip adjacent to the shell as prescribed in Par. H-24 of the Low-Pressure Heating Boiler Code?

Reply: Par. H-24 refers specifically to flanged heads. It is the opinion of the Committee that where the heads used in the construction referred to are flanged for their attachment to the shell, the area thereof may be reduced by a 3-in. strip adjoining the flange and a 2-in. strip adjoining the tubes, as indicated in Par. H-24. If the heads are attached by a method which does not involve flanging thereof, the area may be reduced only by a 2-in. strip adjoining the tubes.

CASE NO. 480

Inquiry: Does the diameter of the tube sheet specified in Par. P-20 of the Code refer to the diameter measured before flanging the sheet, or the outside diameter after flanging?

Reply: It is the opinion of the Committee that the diameter of the tube sheet referred to in Par. P-20 is the maximum measurement of diameter on the outside of the head after it has been flanged.

CASE NO. 481 (In the hands of the Committee)

CASE NO. 482—(Annulled)

CASE NO. 483

Inquiry: Will a boiler that has been constructed in accordance with the requirements of the A.S.M.E. Boiler Code, conform fully to the Code requirements if it is provided with a stamping consisting of a brass plate on which the official Code symbol is etched rather than stamped with one of the official Code symbol stamps furnished by the Society?

Reply: It is the opinion of the Committee that such a form of stamping using an etching of the symbol on a non-ferrous plate will not meet the intent of the requirement in Par. P-332 of the Code.

CASE NO. 484

Inquiry: Is it permissible to connect a low-water signal or alarm of the whistle type to the water-column or water-gage connections of a boiler?

Reply: It is the opinion of the Committee that Par. P-295 of the Code does not permit the connection or attachment of any form of apparatus to the pipes connecting a water column to a boiler that may under any conditions allow steam to escape therefrom. A low-water alarm cannot be considered as the equivalent of a drain connection, the purpose of which is merely to clear out the pipes.

CASE NO. 485

Inquiry: Is it permissible to consider the conical flue sheet of a vertical tubeless boiler which connects the furnace sheet with the top head as an extension or continuation of the furnace sheet from the mud ring to the head, so that the staying thereof may be calculated like that of a long circular furnace, reinforced at the girth seams by the riveted joints applied thereto?

Reply: It is the opinion of the Committee that the straight portion of the furnace sheet in the lower portion of such a design of boiler must be calculated under Pars. P-239 or P-240 pertaining to plain circular furnaces, or if it exceeds the limits of Par. P-240 the sheet must be stayed as a flat surface. The conical portion of the heating surface which is a frustum of a cone may be calculated in accordance with the requirements of Par. P-231 or it may be stayed as a flat surface.

CASE NO. 486

Inquiry: Is it permissible, under the requirements of either Par. P-295 or P-321, to so arrange the water connection between a boiler and a water column that there may be a pocket in the pipe which may cause the lodgment of sediment, even though a cross is provided to facilitate cleaning?

Reply: The Rules in the Code do not definitely specify the arrangement of water connection that shall be made between the boiler and the water column, but it is the opinion of the Committee that this water connection should be so made that the water-column blow-down connection can effectually drain all of the water connections between the column and the boiler.

Addenda to Code

AS A RESULT of criticisms of the requirements in Section IV of the Code for the calculation of sizes of safety valves for low-pressure heating boilers and claims that they are inapplicable under all conditions of practice in the field, the Boiler Code Committee has carefully reviewed this subject and, after due investigation, has formulated the following proposed revision of these requirements:

REVISE PARS. H-51 AND H-104 TO READ AS FOLLOWS:

Every safety valve or water-relief valve shall have plainly stamped on the body or cast thereon the letters A.S.M.E. STD., in such a way that the markings cannot be obliterated in service, the manufacturer's name or trademark, and the pressure at which it is set to blow. The seats and disks of safety or water-relief valves shall be made of non-ferrous material.

REVISE FIRST SECTION OF PARS. H-53 AND H-106 TO READ AS FOLLOWS:

The minimum size of safety or water-relief valve or valves for each boiler shall be governed by the amount of the grate area as given in Table H-6 (or H-10) or H-7 (or H-11).

REVISE TABLES H-6 AND H-10 TO READ AS FOLLOWS:

MINIMUM ALLOWABLE SIZES OF SAFETY VALVES FOR STEAM HEATING BOILERS

Safety Valve			
Diameter, in.	Area, sq. in.	Discharge Capacity, lb. per hr.[1]	Area of Grate, sq. ft.
1/4	0.0491	15	1
3/8	0.1104	30	1.5
1/2	0.1963	60	2
3/4	0.4418	130	3
1	0.7854	230	4
1 1/4	1.2272	360	6.5
1 1/2	1.7671	515	9
2	3.1416	920	14
2 1/2	4.9087	1435	19
3	7.0686	2070	24
3 1/2	9.6211	2810	29
4	12.5660	3675	34
4 1/2	15.9040	4650	39

[1] Capacity of safety valve based on 33 1/3 per cent overpressure, valve set to relieve at 15 lb. per sq. in.

NOTE: The foregoing table is based upon the following formulas:

Where grate area does not exceed 4 sq. ft. } Diam. of safety valve, in. $= \frac{\text{Grate area (sq. ft.)}}{4}$

Where grate area exceeds 4 sq. ft. } Diam. of safety valve, in. $= \frac{\text{Grate area (sq. ft.)}}{10} + 0.6$

If liquid or gaseous fuel is used a grate area shall be assumed equal to that which would be required if coal were used for fuel.

REVISE TABLES H-7 AND H-11 TO READ AS FOLLOWS:

MINIMUM ALLOWABLE SIZES OF WATER RELIEF VALVES FOR WATER-HEATING BOILERS AND FOR WATER-SUPPLY BOILERS

Diameter of Valve, in.	Area of Grate, sq. ft.	Rated Capacity in Gallons per Hour 25° Rise	50° Rise	100° Rise
1/2	1.6	540	270	135
3/4	5.6	1440	720	360
1	9.6	2520	1260	630
1 1/4	15.75	5400	2700	1350
1 1/2	27	10800	5400	2700
2	49.5	21600	10800	5400

NOTE: The foregoing table is based upon the following formulas:

Where grate area does not exceed 12.5 sq. ft. } Diam. of safety valve, in. $= \frac{\text{Grate area (sq. ft.)}}{16} + 0.4$

Where grate area exceeds 12.5 sq. ft. } Diam. of safety valve, in. $= \frac{\text{Grate area (sq. ft.)}}{45} + 0.9$

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Metallurgy for Mechanical Engineers

MEMBERS of the Society who received their engineering training ten or more years ago will recall that the courses in metallurgy then taught dealt largely with the smelting and refining of metals from their ores. These were considered the special interest of students in mining and were generally taken by few mechanical engineers. The use of the microscope for the examination of metals was confined to laboratory research, and few there were who were competent to draw correct conclusions from microscopic studies.

How engineering practice has changed in a few years! Now one seldom buys condenser tubes without requiring photomicrographs to indicate grain size. Special steel castings and various alloy products are photomicrographed in the course of ordinary production. Welds, bends, and heat-treated sections are examined under the microscope, and accurate deductions can be formed from such studies. The microscopic study of metals has thus become a part of our industrial and commercial practice.

Metallography is thus established as a feature of present-day engineering practice. As more knowledge of the art develops, it will be used still more widely. There is every probability that metallographic methods will be quite widely used in the coming years. Engineers will therefore need information on this subject so that they may deal intelligently with problems involving metals and their application.

Busy engineers have little opportunity to study the various able works on this subject. Many of these are quite technical in their treatment and go into greater detail than is necessary for the average engineer. The Publication Committee of this Society believed that a series of articles on the subject of the newer metallurgy written in simple language, would be welcomed by our members. Your editor arranged with an engineer familiar with the subject for the preparation of such a series, and the first article appears in this issue.[1]

The subject is not an easy one to treat in a popular manner, for it involves some of the later concepts of matter, some physical chemistry, and many new ideas associated with the heat changes and heat treatment of metals. In fact, specialists are not in complete agreement regarding the nature of many of these phenomena. The author of the article has endeavored to maintain a judicial attitude on such subjects and has presented what seems to him to be the more generally accepted views. During their preparation these articles were reviewed by several engineers familiar with the subject, and their suggestions have been incorporated where possible.

While these articles cannot be expected to make expert metallurgists of our members, it is hoped that they will familiarize each reader with the terminology of the subject and enable him to have a clearer appreciation and a better understanding of the preparation, use, and interpretation of photomicrographs with which he may have to deal in his professional endeavors.

A. G. CHRISTIE.[1]

[1] The article published in this issue will be followed by several others devoted to the subjects of crystalline structure of metals; heat treatment of metals; determination of properties of metals; cast iron and associated materials; and alloy steels and irons.—EDITOR.

Standardizing Drafting-Room Practices

IN THIS issue of MECHANICAL ENGINEERING Mr. F. W. Ming presents an exceedingly interesting and what looks to be a very valuable piece of pioneer work in standardization. Mr. Ming in his effort to secure information regarding drafting-room procedures that are in vogue in commercial organizations, corresponded with 120 manufacturing firms, and the results of his questionnaire are recorded briefly in his article.

A definite conclusion which can be drawn from Mr. Ming's work is the fact that there is an immediate need for standardization in American drafting-room practice. Mr. Ming shows where many important details of the language of the drafting-room might be placed on a common basis, but the question is a much broader one. Standardization of drafting-room practice involves besides the size of drawings such fundamental matters as the size of files and the form and arrangement of drawings. It also includes the method of indicating dimensions and the best method of showing tolerances.

Methods of indicating tolerance limits on drawings were discussed in the correspondence columns of the April issue of MECHANICAL ENGINEERING. The many methods which are in vogue or which may be used may lead to misunderstanding as to exactly what is required. The United States Government is seeking diligently a proper method which will be universally understood in its various departments and by the many suppliers of material to the Government.

In its broad aspect, the standardization of American drafting-room procedure should greatly facilitate the interpretation of specifications, it should decrease the costs of preparing drawings for all types of machinery and mechanical devices, and, through greater mutuality of understanding, should lead to economies which cannot always be measured in dollars and cents.

The wholehearted approval with which Mr. Ming's efforts were viewed by a large number of progressive manufacturers indicates that a standardization project properly set up and carried through will be welcomed by the industries of America.

E. C. PECK.[2]

The Obligation of Safety in Engineering

IT IS a fact that safety engineers are still compelled at times to build guards for and even to change designs of equipment, notwithstanding such equipment may have been but recently purchased, and accordingly would be expected to be up to date in all respects.

The purchaser is somewhat to blame for this situation, as he has usually stressed the necessity for high efficiency and quality as well as low price, giving insufficient thought to safety features, with the result that the apparatus has tended to reflect most strongly these characteristics, and not infrequently at the expense of safety. It must be admitted, however, that designers, manufacturers, and selling agencies have in many instances failed to appreciate the safety problem at its full value.

An evidence of this is the entire omission of the subject of safety

[1] Professor of Mechanical Engineering, Johns Hopkins University, Baltimore, Md. Manager, A.S.M.E.

[2] Chairman, A.S.M.E. Standardization Committee.

from the meeting programs of many organizations which should be vitally interested, or else its relegation to an obscure place in their discussion; and only recently has there commenced to be a realization on the part of such organizations of the necessity of according it recognition.

Safety, instead of being the simple subject it was originally thought, is now seen, by those who have studied it, to be one of the most complex, and it would be a bold individual indeed who would attempt to define its field.

This failure to appreciate the problem is largely due to the lack of contact between manufacturer and ultimate user, and has led not only to many installations of equipment being either wrongly made or not applied to best advantage, but, what is of even more importance, the user has been prevented from transmitting back to the manufacturer data gained as the result of experience, which, if embodied in the person of a designer, would command a large salary.

It is believed that a closer coöperation between the National Safety Council, whose membership contains a very large number of experienced safety engineers, representing many varied industries and utilities, and leading organizations like The American Society of Mechanical Engineers, together with the various trade associations in each industry, will assist in bridging this gap.

With this idea in mind the officials of both organizations are endeavoring to enlarge the present scheme of joint semi-annual meetings to include meetings as well between the local chapters throughout the country; and it is a foregone conclusion that if present plans can be carried into effect, the cause of safety will have received a most decided impetus.

C. B. AUEL.[1]

Oil and Gas Power Week

DURING the week of April 20 to 25 there were over one hundred meetings of chemists, engineers, operating men, and industrialists throughout the country to review recent progress in the use of oil and gas for power and to point out the need for improved technique and greater economy in their use. Seventeen national technical and governmental bodies coöperated in the planning of the program for the week under the leadership of a committee consisting of Dr. William F. Durand, Chairman, James F. Norris, J. Edgar Pew, C. E. Lucke, W. Trinks, L. H. Morrison and William E. Bullock, Corresponding Secretary. Engineers and technologists in thirty-four states assisted in the actual conduct of the meetings.

The National Committee announced an award of a cash prize of one hundred dollars for the best contribution suggesting means of conserving oil and gas for power purposes, either in the form of a paper presented at one of the meetings throughout the country, or of a written discussion of a paper, or of an original essay not exceeding five thousand words. The National Committee will act as judges and contributions must be in their hands not later than June 1, 1925.

The results of this week of intensive effort and of general discussion of problems in the oil- and gas-power field cannot be quickly evaluated. That it will be of importance in securing greater understanding of the problems involved in one important phase of power generation can be readily conceded, however. In a recent communication Dr. Lucke, one of the members of the National Committee for Oil and Gas Power Week, indicates one useful result that should come. He writes:

"One useful result of the Oil and Gas Power Week activities is already assured, and that is a better understanding of each other by the several groups concerned through a discussion of their respective viewpoints. Out of understanding must come progress, and no progress is possible without understanding.

"As an example of misunderstanding that may be cleared up, an editorial in *Industrial and Engineering Chemistry* of March, 1925, may be cited. According to the editor, 'The automotive engineer for example, assumes an unlimited supply of a liquid fuel of definite composition and properties. Thus far he has given too little attention to the necessarily changing character of this material and has left comparatively untouched the very vital problems of flame propagation, detonation, carbon formation, and the like, which are really fundamental to the proper performance of the engine he designs.'

"This is very interesting but it is not true. The fact that the editor of *Industrial and Engineering Chemistry* should make such a statement is of itself conclusive proof that he knows little or nothing of what engineers have been doing or are doing with internal-combustion engines. No doubt what he says is representative of chemists as a class. Gas and Oil Power Week should correct these impressions. As soon as the chemist knows the viewpoint of the engineer he will be in a position to coöperate in a really effective manner.

"It may confidently be said that all that is really known about fuel and its utilization in internal-combustion engines has been discovered by engineers and not by chemists, and the same is true about lubricants.

"No more is it true that engineers are insisting upon or assuming an unlimited supply of a given fuel of predetermined properties. We may make appliances to utilize a given fuel just as the chemist may endeavor to produce fuel of a given property, suited to any one appliance. There has been among chemists an undue amount of attention to the problem, assumed to be the real one, of producing in various ways a fuel of given properties adapted to an existing utilizing apparatus. On the other hand, engineers have not imposed this condition at all but have done a huge amount of work of adapting the appliance to the fuel.

"The oil engine, and especially the development of the solid-injection oil engine, is an example of the latter activity, as are the various gasoline-producing processes examples of the former.

"The more complete the exchange of ideas between different groups of engineers and between physicists and chemists on the one hand and engineers on the other, the more rationally will our industrial problems be solved, and the more quickly. Each has something to learn from the other, and Gas and Oil Power Week should make this clear and mark a real step in accomplishment in the desired direction."

Efficiency of More than 100 Per Cent

IN A PAPER presented by Oscar Brunler before a joint meeting of the Institution of Chemical Engineers and the Chemical Engineering Group in London on Feb. 11, 1925, a statement was made that in certain cases in practice more than 100 per cent efficiency was obtained. This means that the amount of heat required to evaporate the steam developed during a certain period, say, one hour, was greater than the amount of heat contained in the fuel burned during that period as determined, for example, by the bomb calorimeter. This may have been due, of course, as the author himself stated, to some error in the determination of experimental values, but he claims that the experiments were carried out so carefully that it is unlikely that such an error might have happened. If so, then we are dealing with still another case where a greater efficiency than the theoretical has been obtained.

During his experiments to manufacture nitrates Hausser observed that sometimes efficiencies were obtained that surpassed the theoretical output by 90 to 120 per cent. Similar observations were made by Haber and Koenig in experimenting with electric arcs to manufacture nitric acid. Hahn obtained a calorific value 10 to 12 per cent higher than the theoretical calorific value of the fuel in passing a stream of steam into an oil flame. To these citations may be added a statement made by Lord Kelvin as far back as 1852, in which he pointed out that in heating a building by burning coal, one might employ an indirect process comprising a heat engine and a "warming machine" driven by the engine, by means of which the heat delivered to the building might be much greater than the heat of combustion of the coal consumed. In other words, the system considered merely from the point of view of coal consumption would work at an efficiency better than 100 per cent.

In a paper presented by A. Altenkirch at the International Congress of Refrigeration in New York and Chicago in 1913, an installation based on this principle of operation was described, and it was claimed that it was actually obtaining in the way of heat and ice an efficiency better than 100 per cent.

Of course, in all such cases there is really no efficiency better

[1] Pres., National Safety Council; Mgr. Employees' Service Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa. Mem. A.S.M.E. Safety Committee.

than 100 per cent and none of them contradicts in any way the law of conservation of energy. There is always in them some source of energy operating which was not taken into consideration initially, a kind of a "hidden asset," and it is due to the neglect of this hidden asset that an apparent efficiency of 100 per cent or better is obtained. In Kelvin's case it is the action of the warming machine. In the case of the Brunler boiler it is some such thing as the action of the ultra-violet rays, which in ordinary boilers is made effective by the presence of a metal wall between the flame and the water; or it may be some kind of an electrical vibration set up by the flame, which again can be effective only when the flame is in communication through a non-absorbing body with the water. There is also the more or less remote possibility that we are dealing here with something in the nature of an atomic break-up of matter, and the observation of certain phenomena occurring in the Sperry searchlight are would lead to the belief that there is at least a chance that something of the sort is taking place.

The important thing about it all is, however, that under certain assumptions—for example, that the total energy of a fuel can be determined by a calorimeter test—efficiencies of combustion in excess of 100 per cent may be obtained. What such efficiencies indicate is not that engineering has succeeded in obtaining something for nothing, but that our determinations of the heat value of fuels may prove to be quite unreliable and defective, which is worth while bearing in mind.

Engineering in Railroading

THE announcement of the retirement of Julius Kruttschnitt as Chairman of the Executive Committee of the Southern Pacific Railroad which followed shortly after the delivery of his address on the Engineer as a Railroad Executive, which forms the leading article of this issue, emphasizes the fact that his personal contribution to the solution of the transportation problem of the country has been a great one.

Mr. Kruttschnitt in his address has presented an analysis of the many complicated problems to be solved daily in railroad operation and of the purposes to be accomplished in the transportation industry. He has indicated the trend of technical development on railroads to reduce the cost per transportation unit. He has divulged the secrets of his success in railroad operation. And his conclusion is that men trained in engineering are the ones best fitted to coördinate and guide the numerous operating activities on railroads and to secure the maximum output of salable product at minimum cost.

Engineering students have a definite impression of the aggressive attempts that are made by the electric manufacturing organizations, by some public-utility groups, and by representatives of other forward-looking industries to secure the best students each year to enter their industries. Large manufacturing organizations have frequently stated that it is their policy to secure technically trained men as the basis for their industrial growth. Railroads have never entered into this competition for technically trained men, and the schools where courses in railway engineering are taught are very few. It is indeed stimulating, therefore, that Mr. Kruttschnitt should thus publicly come before the engineering profession and encourage engineers to think of railroading as a life work. However, Mr. Kruttschnitt does point out that a large number of railroad leaders have risen from the ranks by sheer ability and pluck. Mr. Kruttschnitt very wisely, therefore, warns against any activity in the railroad field that will stifle the ambition of the large number of men in railroad service who have not had the advantage of college or technical education.

Arbitration Laws

IMPORTANT steps have recently been taken to reduce the delay, expense, and annoyance that industries suffer through recourse to court action to settle business disputes. On February 12, 1925, President Coolidge signed the United States Arbitration Act, and on February 25, 1925, Governor Walter M. Pierce approved an arbitration act for the state of Oregon. New York and New Jersey have had arbitration acts since 1920 and 1923, respectively. The principles embodied in these four laws are fundamentally the same and may now be considered to represent American policy for the settlement of business disputed by arbitration instead of through litigation. According to this policy, an agreement to arbitrate an existing dispute or the inclusion in a contract of a clause stipulating that any dispute arising under the contract is to be arbitrated, is valid, enforceable, and irrevocable, and the award made by the arbitrator becomes the judgment of the Court. The arbitrators, who are selected by the parties to the controversy, have the power of a judge to issue subpoenas, compel the production of books and papers, place witnesses under oath, etc. Hearings are private and proceed without technical rules in evidence, each side telling its story in its own way. Disputes can therefore be arbitrate sspeedily and inexpensively, and, because the proceeding is voluntary and amicable, friendly business relationships between parties are usually retained.

The United States Arbitration Act provides for the arbitration of disputes arising out of contracts, maritime transactions, or commerce among the states or territories or with foreign nations. It does not apply to contracts of employment of seamen, railroad employees, or any other class of workers engaged in foreign or interstate commerce.

The procedures embodied in these arbitration acts should provide for prompt settlement of disputes with the elimination of a great deal of industrial waste. Under such conditions engineers in industry will be thoroughly sympathetic with efforts made to establish a legal basis for commercial arbitration. Arbitration bills similar to those at present in force are up for consideration by the legislatures of California, Indiana, Massachusetts, Minnesota, Mississippi, North Carolina, and Rhode Island.

Testimonial to Edward Dean Adams

THE remarkable achievements of Edward Dean Adams in engineering and finance were extolled at a testimonial dinner on April 9, the date of his seventy-ninth birthday. Over three hundred friends and associates of his long, eventful career were present to extend felicitations, and over three hundred others sent greetings from all parts of the world. The function was a wonderful tribute to a man whose life has embodied splendid contributions to engineering achievement and financial leadership, as well as patronage of science, art, and literature.

Dr. William F. Durand, President of The American Society of Mechanical Engineers, acted as master of ceremonies and introduced the speakers of the evening, A. Monroe Grier, President of the Canadian Niagara Power Company, and William Nelson Cromwell, a corporation counselor of international standing.

Mr. Grier spoke specifically of Mr. Adams' achievement in making the dream of harnessing Niagara a reality, which he brought about as the first president of the Cataract Construction Company. He paid tribute to the genius of Mr. Adams in guiding the deliberations of the International Commission which settled the technical problems involved, including the major items of voltage and frequency. He stressed Mr. Adams' high integrity and organizing ability which secured the financial support of the elder Morgan. Mr. Grier also pointed out as important elements in the success of this project Mr. Adams' unswerving faith in alternating current, in large direct-connected generating units, and in long-distance transmission on a big scale. All of these were necessary to the commercial success of the project and were advanced in the face of great opposition. Mr. Grier characterized Mr. Adams' achievement as an exemplification of individual enterprise and pioneer courage which marks the full vigor of the English-speaking world.

Mr. Cromwell traced the important achievements of Mr. Adams in financing and upbuilding of a large number of industrial and transportation organizations. He also dealt with Mr. Adams' association with scientific, artistic, educational, and charitable organizations, and paid high tribute to his capacity for friendship, his modesty, and his intense interest in the broader contacts of life.

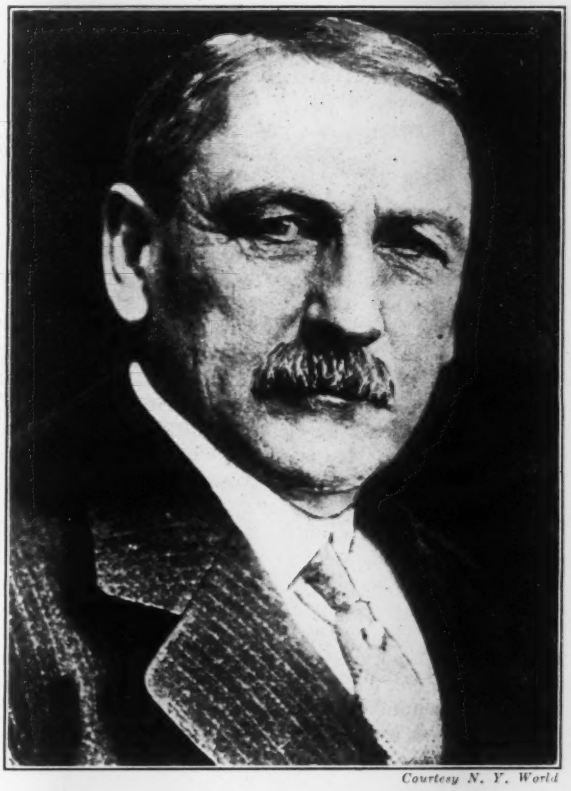
At the close of these two addresses Dr. Durand presented to Mr. Adams an illuminated testimonial of esteem which was embodied in a friendship volume. In response Mr. Adams expressed deep appreciation for the honor that had been conferred upon him at the dinner.

John F. Stevens Receives John Fritz Medal

In Recognition of His Distinguished Services as a Civil Engineer, Particularly in Connection with the Panama Canal and as a Builder and Administrator of Railways

PRESENTATION of the John Fritz Medal was made to John F. Stevens in the Engineering Societies Building on Monday evening, March 23, 1925, in recognition of his distinguished services as a civil engineer, particularly in connection with the Panama Canal, the building of railroads, and as administrator of the Chinese Eastern Railway and of the Trans-Siberian Railway. Addresses were made by Ralph Budd, president of the Great Northern Railway, and by the Hon. Roland S. Morris, former Ambassador from the United States to Japan. Presentation of the medal was made by Charles F. Rand, Chairman of the John Fritz Medal Board of Award. John R. Freeman presided.

Mr. Stevens has had one of the most spectacular careers of any engineer who has ever been honored by the award of the John Fritz Medal. The international aspect of his achievements is eloquently proven by the unusual honors which have been bestowed upon him. He is an officer of the Legion of Honor of France, the recipient of the Distinguished Service Medal of the United States, of the Order of the Rising Sun of Japan, of the Order of the Golden Grain of China, of the Order of the Striped Tiger of China, and of the War Cross of the Republic of Czechoslovakia. Through the award of the John Fritz Medal by the unanimous action of representatives of the four national engineering societies, he has now received the highest honor in the power of the American engineering profession to bestow.



Courtesy N. Y. World

JOHN F. STEVENS

The importance of John F. Stevens' contribution in the field of engineering as applied to transportation problems, and in the broader field of international diplomacy, was the theme of the addresses at the presentation ceremonies. Mr. Budd, whom Mr. Stevens describes as "one of my old boys," told the story of Stevens' lifework until he went to Russia. Mr. Morris took up the narrative at this point and discussed the contribution which Mr. Stevens made to the transportation problems of Europe and Asia.

Relating the story of the discovery of Marias Pass, Mr. Budd gave evidence of his keen insight into the characteristics which made Mr. Stevens a successful engineer. Early in 1889 the latter had been assigned the task of locating the best line for a road for James J. Hill through the Rocky Mountains. "A less thorough, less courageous engineer," said Mr. Budd, "would have accepted the general locality of Helena as the most available for crossing the Rockies, as it had been accepted almost without question for eighty years, and would have located the Pacific extension of the Great Northern through some feasible outlet known to exist in that part of the mountains. What John F. Stevens did was characteristic of the man, his methods and his ability. . . . . .

"His reconnaissance carried him well into the winter, and his persistent search enabled him to report that on December 11, 1889, he had located and surmounted Marias Pass, about 125 miles north of the passes in the vicinity of Helena and on the line of the direct route westward. . . . . On the last lap of the exploration of Marias Pass he was accompanied only by a half-breed Indian, as no one else would venture into the mountains so late in the year. Carrying their packs on their backs they had reached a point about five miles from the actual summit when Stevens' companion became exhausted and had to be left at camp, if an open fire on ground cleared of two feet of snow can be called a camp. From there he went alone through the Pass and far enough to make sure he was in Pacific drainage. Alone that night at the summit he tramped to and fro to keep from freezing, and in the morning came back to his Indian only to find the fire out and the fellow half-frozen. . . . . .

"At one stroke the discovery of Marias Pass shortened the proposed line to the Coast by over 100 miles, afforded far better alignment, much easier grades, and much less rise and fall. In grateful recognition of this service the Great Northern Railway has caused a heroic bronze statue of Mr. Stevens, as he then appeared, to be executed, and it will stand permanently where he spent that memorable night in December, 1889."

From his engineering achievements in the West Mr. Budd followed Mr. Stevens to the Panama Canal where he went in 1905 with work practically at a standstill, the Isthmus in an unhealthful condition, the rainy season at its height, and the only means of transportation the Panama Railroad, which was practically broken down. He went about his tasks there quietly and unassumingly, but unhesitatingly. He laid plans and created an organization so efficiently that before the end of 1906 announcement was made that the Canal could be formally opened by January 1, 1915. The period of planning and organizing was nearly over by 1907, and with an able administration, success was assured. Mr. Stevens returned to the States in April of that year, and probably the greatest tribute ever paid him was the universal regret felt among the 30,000 workers of all classes and conditions when they knew a change of administration was at hand.

Former-Ambassador Morris told of Mr. Stevens' remarkable work in Russia where he went in May, 1917, as head of the American Railway Advisory Commission to study the problem of Russia's railroad breakdown and was subsequently appointed advisor to the Russian Government under the Kerensky régime. The difficulties attending the problems of keeping an avenue open through which raw materials and food might flow by means of the Chinese Eastern Railway and the Trans-Siberian Railway were accentuated by international complications which were the results of the times and the War. Japan, China, Great Britain, and the United States were all interested in keeping Siberia in a condition industrially which would be working toward eventual stabilization. In 1919 Mr. Stevens was appointed president of the Inter-Allied Technical Board, which faced the problem of working out the operation of the Trans-Siberian system in a country torn by civil war and menaced by the jealousies of factions and conflicting nationalities.

Referring to this part of Mr. Stevens' career, Mr. Morris said: "We have Mr. Stevens to thank that today two great Russian highways are preserved to the Russian people and open to world trade. The time came when our own troops guarding the railroads in Siberia were removed. Popular feeling was very much against it and the men wanted to go home. But at the request of the Russians, Mr. Stevens consented to remain with them, and with only one or two assistants he continued to superintend the operation of the great Trans-Siberian system, thus occupying a

position unique in the history of American engineering. Quite alone he completed the task he had undertaken. From a small apartment in Harbin he exercised a moral influence during that period of reconstruction in the Far East the results of which will continue to operate long after our generation shall have passed away. It was an extraordinary service which he rendered and we, his friends and co-workers, are proud to join with his professional colleagues in giving him the supreme recognition of a task faithfully performed."

President Appoints Muscle Shoals Commission

HOPE that was aroused by the adoption by Congress of a resolution asking the President to appoint a commission to report on the Muscle Shoals project has been dashed by the announcement of those who are to serve on this commission.

John C. McKenzie, a former congressman from Illinois, will act as chairman, and the other members are Nathaniel B. Dial, former senator from South Carolina, Russell F. Bower, of the American Farm Bureau Federation, Prof. Harry A. Curtis, of Yale University, and William McClellan, of New York.

Professor Curtis is professor of chemical engineering at Yale. He was called in consultation by the United States Department of Agriculture when reorganizing its fertilizer research. He was at one time executive officer of the Nitrogen Research carried on by the Army. He directed the world nitrogen survey conducted recently by the Department of Commerce. He is a graduate of the University of Colorado and holds a degree from the University of Wisconsin.

Mr. McClellan is an electrical engineer, a graduate of the University of Pennsylvania, and at one time dean of Wharton School. He is a past-president of the American Institute of Electrical Engineers and has had broad experience in the electrical field. He is at present a member of the firm of Payne, McClellan, and Campion, and president of McClellan and Junkersfeld, consulting engineers.

Ex-Senator Dial has large cotton-mill holdings and is familiar with the power problems of the Southeast. Mr. Bower has been interested in the relationship of Muscle Shoals to agriculture and has been employed for some time by the American Farm Bureau Federation.

The Commission is empowered to examine into and report to the President upon the most practical method or methods of utilizing to the best advantage the Muscle Shoals facilities. One hundred and twenty thousand dollars is available for the Commission's use.

The Low report presented by a Committee of the American Engineering Council expressed unanimous agreement that no disposition of the Muscle Shoals plant should be decided upon until a thorough investigation of the whole problem had been made by a disinterested technical commission. Of the newly appointed commission only two are technicians, and though both are men of excellent standing and high caliber, they are pitted against three politicians who have publicly declared themselves on the disposition of Muscle Shoals. The successful performance by the two technicians of the task of collecting all of the facts and bringing to bear sound judgment upon the problem, seems almost too much to expect.

The Patent Office

BY EXECUTIVE order President Coolidge has transferred the Patent Office from the Department of the Interior to the Department of Commerce. This move is in accord with the proposed federal reorganization recommended by the joint Congressional Committee, but it is the only step possible without Congressional action.

This change brings to the Department of Commerce the supervision of inventions that have built up our modern industrial system and a building nearly ninety years old whose architecture has inspired many public buildings in Washington and which has housed many Government bureaus and offices in their early stages of development.

The Secretaries of the Interior and of Commerce joined in the recommendation that the jurisdiction of the Patent Office be changed because of the obvious purpose of the Patent Office as a scientific and legal instrument for developing industry. The Patent Office is closely related to the Bureau of Standards and the Bureau of Foreign and Domestic Commerce, both of which are in the Department of Commerce, so that the placing of the Patent Office also in the Department of Commerce should bring about some economies in operation.

In a public statement made shortly after taking over the Patent Office, Secretary Hoover announced that it would be his first duty to undertake a vigorous campaign to remove present injustices toward American patentees and American manufacturers that exist because of the character of the patent laws in other countries. At the present time in many foreign countries the American patentee is required to manufacture continuously in those countries under his patent or lose his patent rights. There is no such requirement in the United States. As a consequence American inventors and manufacturers have been forced to establish factories abroad to protect their inventions, whereas foreign patentees have been able to use their United States patents to prevent manufacture here. The foreign patentee by registering his patent in the United States can hold it for seventeen years and prevent manufacture of the article in the United States.

At an International Convention for the Protection of Industrial Property to be held at the Hague on October 8, 1925, the American Government will make proposals for the equitable treatment of patentees in all countries. Failing to secure justice in this convention, Secretary Hoover proposes to ask for a complete revision of the patent laws of the United States to secure it.

Through the support of Congress and the administration of the Commissioner of Patents, the period after the receipt of an application until that application could be considered has been reduced from fifteen months—which was the condition four years ago—to seven months. Secretary Hoover hopes that continued vigorous administration will bring the Bureau to date within two years.

When the Patent Office was under the Department of the Interior, Secretary Work appointed a committee to investigate patent procedure and make recommendations to secure more prompt and thorough consideration of patent applications. Secretary Hoover has continued this committee and requested the A.S.M.E. to appoint two engineers experienced in the organization of office methods. Dr. Durand has appointed Wallace Clark and W. H. Leffingwell, of New York.

Reorganizing the Engineering Work of the Government

ENGINEERS of the United States have given a great deal of consideration from time to time to general problems of Government reorganization, paying particular attention to the importance of bringing the various engineering functions of the Government into a more logical relationship. The American Engineering Council is now, through its Committee on Government Relationship—of which Gardner S. Williams of Ann Arbor is chairman, taking up the various plans for Government functionalization and will submit the matter for discussion to the member bodies of the American Engineering Council.

Reorganization plans are first directed to the Department of the Interior which has been aptly characterized as "Uncle Sam's waste basket." The plan to be supported by the American Engineering Council provides for two Assistant Secretaries of the Interior, known as the Assistant Secretary for Public Domain and the Assistant Secretary for Public Works. The Assistant Secretary of Public Domain is to have charge of the administration of Alaska and Hawaii, the operation of Indian Lands and Reservations, the General Land Office, the Geological Survey, the National Park Service, and the Federal Power Commission. The duties of the Assistant Secretary of Public Works will include the supervision of the operation of public roads, supervising architect's office, the Alaskan Engineering Commission, Reclamation Service, the Board of Road Commissioners of Alaska, the Bureau of Engineers for Rivers and Harbors, the Mississippi River Commission, the Colorado Debris Commission, the Commission of Fine Arts, Superintendent of State, War and Navy Buildings, the Architect of the Capitol, and the Rock Creek and Potomac Parkway Commission. The majority of these activities have been transferred from the Departments of War, Agriculture and Treasury.

Advisory Committee on Standardization

To Focus the Influence of Industrial Leaders upon the National Standardization Program: Coöperative Effort of Industry and Government under the Guidance of the A.E.S.C.

THE American Engineering Standards Committee has secured the coöperation of American business and will have the support of its power and prestige in the extensive program of standardization which is fast gaining momentum. The first step in the campaign is the formation of a committee of five first-line executives, to act as an advisory body to the A.E.S.C. This committee will consist of J. A. Farrell, president of the U. S. Steel Corporation; G. B. Cortelyou, president of the Consolidated Gas Company, New York; J. W. Lieb, vice-president of the N. Y. Edison Company; L. F. Loree, president of the Delaware & Hudson Company, and Gerard Swope, president of the General Electric Company.

In focusing the united influence of big industries of national and international ramifications on the American Engineering Standards Committee program, the committee of five just formed will emphasize what is regarded as the fundamental principle of standardization: namely, that standardizing must facilitate and stimulate, and not hinder, industry.

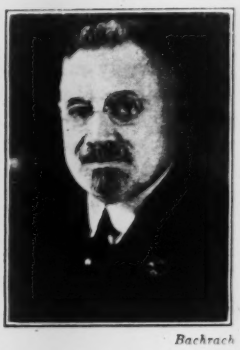
The committee will assist in keeping executives in touch with the national movement in its development, in extending its influence and support both intensively and extensively among industrial groups and in bringing about the fullest coöperation along right lines between industry and government in standardization work, and particularly in the solution of the problem of industrial waste, into which Secretary Hoover has thrown the resources of the Department of Commerce.

The acceptance of appointment on this committee by men of such high standing marks a definite recognition of the fact that standardization has now become a managerial problem of the first rank in industrial production, distribution, and utilization, and as such deserves the fullest industrial support.

Underwood and Underwood

GEO. B. CORTELYOU

JAMES A. FARRELL



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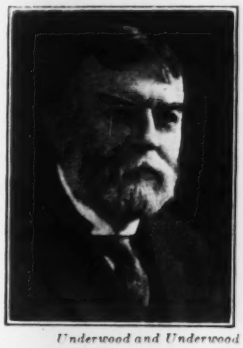
JOHN W. LIEB



Underwood and Underwood

L. F. LOREE

Underwood and Underwood

GERARD SWOPE

The American Engineering Standards Committee, organized in 1918 by the four national engineering societies, has been engaged in standardizing work on a national basis since that time, representing a membership of 34 national organizations, including nine engineering societies, 18 industrial associations, and seven departments of the Federal Government. It serves primarily as a national clearing house for engineering and industrial standardization, with the purpose of coördinating standardization work in the individual industries effected by associations, societies, and governmental agencies into a unified system of national standardization.

It is significant that about 250 organized trade, technical, industrial and governmental bodies are coöperating with the American Engineering Standards Committee, and have about 1200 accredited representatives on its various working sub-committees. This extensive participation in the Committee's work assures the acceptance and actual adoption of the national standards thus worked out and approved. To date, some 170 standardization projects are actively under development or have reached the stage of approved standards.

The procedure of the A.E.S.C., which relies on the round-table conference for the solution of the serious problems of standardization, has met with unqualified success, as demonstrated by the rapid growth of projects and the excellent progress in securing approved standards. The conference method has decided advantages in that it focuses the attention of all organizations and interests concerned on the subject, affords a definite access to the technical and trade press for giving wide publicity to the project, and gives early opportunity for opposing interests to smooth out difficulties under the most advantageous circumstances.

In a real sense the A.E.S.C. is a movement rather than a formal organization—a coöperative movement which will be greatly helped by the guidance of the Advisory Committee.

This new plan to intensify the national standardization movement by lending the American Engineering Standards Committee the support of an advisory committee made up of leaders of the largest industries of the country, had its inception at a dinner given by J. A. Farrell, president of the U. S. Steel Corporation; John R. Freeman, president, Manufacturers Mutual Fire Insurance Company, Guy E. Tripp, chairman, and E. M. Herr, president of the Westinghouse Electric and Manufacturing Company. In addition the following were present at the dinner:

WALTER R. ADDICKS, Vice-President, Consolidated Gas Company
M. W. ALEXANDER, Managing Director, National Industrial Conference Board
W. W. ATTERBURY, Vice-President, Pennsylvania Railroad
WILLIS BOOTH, President, International Chamber of Commerce
JOHN A. COE, President, American Brass Co.
C. P. COLEMAN, President, Worthington Pump & Machinery Co.
EDWARD J. CORNISH, President, National Lead Company
GEO. B. CORTELYOU, President, Consolidated Gas Company
J. M. DAVIS, President, Manning, Maxwell & Moore
HENRY L. DOHERTY, President, Henry L. Doherty & Co.
COL. JOHN H. FINNEY, Mgr., Washington Office, Aluminum Company of America
NORMAN J. GOULD, President, The Gould Manufacturing Company
BANCROFT GHERARDI, Vice-President, American Telephone & Telegraph Co.
DR. FRANK B. JEWETT, Vice-President, American Telephone & Telegraph Co.
ROBERT LAMONT, President, Steel Foundries Corporation
J. W. LIEB, Vice-President, New York Edison Company
L. F. LOREE, President, Delaware & Hudson Company
JAMES H. MCGRAW, President, McGraw-Hill Company
E. J. MEHREN, Vice-President, McGraw-Hill Company
FRANK W. SMITH, Vice-President, United Electric Light & Power Co.
L. S. STORRS, President, The Connecticut Company
CHARLES B. SEGER, President, United States Rubber Company
A. A. STEVENSON, Vice-President, Standard Steel Works Company
GERARD SWOPE, President, General Electric Co.
A. W. WHITNEY, Associate General Manager, National Bureau of Casualty & Surety Underwriters
C. E. SKINNER, Chairman, American Engineering Standards Committee
P. G. AGNEW, Secretary, American Engineering Standards Committee.

The International Electrotechnical Commission met at The Hague from April 16 to 23. Representatives from the United States included Dr. C. H. Sharp, president of the U. S. National Committee, Dr. C. O. Mailloux, honorary president of the Commission and also of the U. S. Committee, C. E. Skinner, East Pittsburgh, Pa., L. E. Elden, Boston, Mass., S. E. Doane, Cleveland, Ohio, and E. A. Snyder, Pittsfield, Mass.

A.S.T.M. Metal Committees

ELEVEN committees constituting the metal section of the American Society for Testing Materials held meetings at the Bellevue-Stratford Hotel in Philadelphia on March 18, 19 and 20, which were attended by about 234 members and visitors. These committees were Committee A-1 on Steel, Committee A-2 on Wrought Iron, Committee A-3 on Cast Iron, Committee A-4 on Heat Treatment of Iron and Steel, Committee A-5 on Corrosion of Iron and Steel, Committee A-9 on Ferro Alloys, Committee B-1 on Copper Wire, Committee B-2 on Non-Ferrous Metals and Alloys, Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys. Committee D-14 on Screen Wire Cloth, and Committee E-4 on Metallography.

The Committee on Heat Treatment of Iron and Steel will submit to the A.S.T.M. at its annual meeting in June an extensive revision of the recommended practice for the heat treatment of case-hardened carbon steel. The Committee will at that time also propose a program of fundamental research in the heat treatment of wrought iron.

The Committee on Wrought Iron is actively engaged in the chemical analysis of bar iron. This committee also joins in recommending research in the heat treatment of wrought iron.

At the meeting of the joint Research Committee of the A.S.M.E. and the A.S.T.M. on Effect of Temperature on the Properties of Metals, details of the test program and methods of financing were discussed.

The Committee on Cast Iron plans a study and tabulation of existing practice in varying the composition of pig iron for different grades of casting. This Committee voted to adopt a revised test bar 1.2 in. in diameter and tested on supports 18 in. apart.

The Committee on Corrosion of Iron and Steel received a proposed plan for field tests of metallic coatings. This Committee has a number of projects under way to test the corrosive effects on galvanized sheets, structural shapes, wire fencing, etc.

The Committee on Steel adopted for submission to the Society in June tentative specifications for structural silicon steel. The Committee will ballot by mail on tentative specifications for carbon-steel castings for valves, flanges, and fittings for high-temperature service up to and including 750 deg. fahr. The Committee approved a recommendation that specifications for spring steel be revised to include tolerances that will agree with those adopted by the American Railway Association.

The Committee on Corrosion of Non-Ferrous Metals and Alloys stated that actual test work would begin soon on accelerated corrosion tests on samples of nickel, zinc, lead, copper, aluminum, and Admiralty metal. Six corrosive solutions will be used.

The Committee on Non-Ferrous Metals and Alloys recommended that the Society's specifications for Muntz metal condenser tubes and brass condenser tubes be adopted as standard. New specifications for aluminum-base casting alloys in ingot form will be prepared.

Dr. Carl Benedicks, Director of the Metallographic Institute, Stockholm, Sweden, addressed the members at luncheon on Friday, March 20.

Research in Engineering Education

THE present method of admitting students to engineering courses and the lack of proper vocational guidance for high-school boys are definitely stated as the two outstanding causes for the elimination of a large number of students from such courses in a preliminary report on an investigation of engineering education being conducted by the Society for the Promotion of Engineering Education. Prof. H. P. Hammond, associate director of the investigation, states that the records of approximately seventy thousand students admitted to engineering schools during the past twenty years show that for one hundred admitted forty are graduated and thirty graduate regularly with their class.

Professor Hammond presents some interesting facts about quality of preparation and admission requirements. While a number of institutions express satisfaction with the quality of preparation, and some believe that the last ten years have brought well-defined improvements, a considerable number note a progressive change for the worse. The most serious defects in preparation appear to be in mathematics and in English. This matter of entrance qualifications is important but it is one which the educational institutions can control, and as such is not of immediate concern to the engineering profession.

However, the question of a thorough understanding as to the real purpose of the engineering profession on the part of prospective students is one in which the engineering profession at large is keenly interested and has a direct responsibility. Professor Hammond states that "less than fifty per cent of freshmen after from one to four months of a college course are able to give other than a very vague and ill-founded statement as to the scope of engineering and the work of an engineer, nor do they (as far as the evidence is available from the present studies) have any adequate conception of the particular field of engineering which they have decided to enter." Professor Hammond further suggests that engineering colleges can assist high-school students who contemplate taking an engineering course by providing them with facts regarding engineering as a life work. Undoubtedly the engineering schools are most intimately concerned in securing the right type of material, but the engineering profession as a whole has a responsibility in this matter which it should not transfer entirely to the shoulders of the faculty of the engineering school.

Professor Hammond shows that fifty per cent of the eliminations are due to scholastic difficulties. Studies are in progress to ascertain the more fundamental causes of scholastic failures.

Vehicular Tunnel Claims Another Victim

HERBERT HOOVER once characterized the engineering profession as a group of men whose passion it is to build and construct. This passion is guiding in all engineering problems big and small, and is revealed by the self-sacrifice, the devotion to duty, and the conscientious attention to detail which successful engineering entails. But even in the achievement of the spectacular engineering feat whose magnitude the public can comprehend, there is still no general appreciation of the contribution of the engineer. While it is one of the tragedies of engineering that success does not always bring fame, the truly great engineer feels it not, for he seeks only the satisfaction that comes from having done his work well.

Last December we recorded the passing of Clifford Holland, a master builder of tunnels, on the eve of "holing through" the greatest subaqueous tunnel in the world. Holland's life work was tunnel building, and he achieved success at the cost of his life. His duties as chief engineer of the New York-New Jersey Vehicular Tunnel were taken up by Milton H. Freeman, who in turn sacrificed his life to the work. Mr. Freeman's conscientious devotion to duty had weakened his resistance to disease and he died of pneumonia.

Holland and Freeman are "heroes of peace." Their names should be honored of all men and their careers should be recorded for the inspiration of young engineers.

Eliminating Labor Wastes

THE identity of the interests of the owner, manager, and worker in a modern industrial enterprise with those of the public in the reduction of waste due to misunderstanding and suspicion between the various groups was emphasized at a luncheon of the New York Industrial Round Table on April 11. The topic of discussion was, Eliminate Industrial Waste—Minimize Industrial Controversy.

Alton B. Parker, president of the National Civic Federation, presided, and the gathering was addressed by Herbert Hoover, Secretary of Commerce, William Green, president of the American Federation of Labor, and Gerard Swope, president of the General Electric Company. The attendance was a remarkable cross-section of present-day activity, being made up of bankers, business executives, engineers, labor leaders, and clergy.

The luncheon was a step in the direction of bringing coöperative thinking to the problems of industrial growth. The millenium of peace in industry is still far removed and will come only with a fundamental change in human nature, but with an appreciation of the common interest in cheaper production, much of the bitterness of labor struggles will be lost.

Book Reviews and Library Notes

THE Library is a coöperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The Library and Its Service

THERE appears below a list of references on the Flettner rotor ship which has attracted so much attention recently in marine circles. The list indexes the articles that have appeared in technical periodicals since attention was first directed to the rotor ship.

The list also shows the work that the Library does for subscribers to its reference-card service, for these references were collected day by day as the various periodicals were received and copied on cards which were mailed every week to subscribers. By this arrangement subscribers were kept promptly informed of each new development, with a minimum of trouble and at small expense.

The Library offers reference service of this kind on any engineering topic. The cost varies with the amount of material sent, the minimum charge being ten dollars a year.

Inquiries concerning reference-card service should be addressed to the Engineering Societies Library, 29 West 39th Street, New York.

FLETTNER ROTOR SHIP—ENGINEERING SOCIETIES LIBRARY

Das Walzensegel von Flettner. (Flettner's rolling sail), 1924. (In *Zeit. des Ver. Deut. Ing.*, v. 68, p. 1218.) A brief description of the Flettner rotor ship. Diagrammatic sketches given to show the principle of operation and the type of construction.

Die Aerodynamik der neuen Flettner-Erfindung. (The aerodynamics of the new Flettner discovery), 1924. (In *Zeit. fur Luftschiff.*, v. 28, p. 281–284.) Describes the Flettner rotor ship with illustrations of constructional details, and the principle of the Magnus effect.

Heyn, R. P. Der Magnus Effekt. (The Magnus effect), 1924. (In *Schiffbau*, v. 25, p. 803–806.) Describes the Flettner rotor ship, which uses cylindrical sails. The origin of the name "Magnus Effect" and the early work of Professor Magnus are outlined. Sketches showing principle and construction.

Patzak, C. Der Magnus-effekt und das Flettner Rotorschiff. (The Magnus effect and the Flettner rotor ship), 1924. (In *Kali-Zeit. fur Gewin. Verarbeit. u. Verwert der Kaliz.*, v. 18, p. 364–368.) Some facts about Professor Magnus and his work, with a description of the Flettner rotor ship, its construction and principle of operation.

Rotor Ship. *Shipbldr.* (Feb. 1925), v. 32, p. 107–108.

Flettner's Sailless Ship Explained. *Jl. Am. Soc. Naval Engrs.* (Feb. 1925), v. 38, p. 145–148. (From *Power*, Dec. 30, 1924.)

Flettner Rotor Ship. *Automot. Ind.* (Feb. 26, 1925), v. 52, p. 364–365.

Anton Flettners Erfindungen. *Zeit. des Ver. Deut. Ing.* (Dec. 6, 1924), v. 68, p. 1270.

Anton Flettners Erfindungen. *Zeit. Osterr. Ing. u. Arch. Ver.* (Jan. 9, 1925), v. 77, p. 7–10.

La Roto Flettner. M. Richard. *Bull. Tech. du Bur. Veritas* (Dec. 1924), no. 12, v. 6, p. 226–228.

Rotor Motor for Aerial Transport. *So. Afr. Power Engr.* (Jan. 1925), v. 10, p. 31.

The Flettner Sailless Ship. C. H. Bornemann. *Purdue Engng. Rev.* (Jan. 1925), v. 20, p. 9 and 22.

The Flettner Rotor Ship. Von A. Flettner. *Engng.* (Jan. 23, 1925), v. 119, p. 117–120.

Flettner Rotor Ship. *English Mechanics* (Jan. 16, 1925), v. 121, p. 3–4.

Flettner Rotor and Aircraft. *Aeroplane* (Jan. 28, 1925), v. 28, p. 82.

Magnus Effect. *Marine Engng.* (Feb. 1925), v. 30, p. 95–6.

Flettnerrotorn. I. Malmer. *Teknisk Tidskrift* (Jan. 17, 1925), v. 55, p. 1–5.

Propulsor Flettner, para Barcos. *Anales Asoc. Ing. Inst. Catolico*, v. 3, p. 544–545.

Magnuseffekten. V. Bjerknes. *Teknisk Ukeblad* (Jan. 30, 1925), v. 72, p. 45.

Rotors Flettner. *Bull. Tech. du Bur. Veritas.* (Jan. 1925), No. 1, v. 7, p. 6–8.

Is the Magnus Effect Applicable to Aircraft? A. Klemin. *Aviation* (Feb. 2, 1925), v. 18, p. 127–129.

Das Flettner-Schiff. Schulz. *Brennstoff u. Warmewirtschaft.* (Feb. 1, 1925), v. 7, p. 45–8.

Further Consideration on the Rotorship. *Motorship* (March 1925), v. 10, p. 188.

How Rotor Ship Gets Power. *Marine Rev.* (March 1925), v. 55, p. 90–91.

Notable Italian Works on Hydraulic Engineering Presented to the Library

THE Engineering Societies Library has been enriched by a gift of the fourth edition of the "Raccolta d'Autori Italiani che Trattano del Moto dell'Acque" and of the supplementary "Nuova Raccolta——."

The seventeen volumes that this series comprise were published in Bologna between 1821 and 1845. They contain, apparently, everything of importance on hydraulic engineering that had been written in Italian at that time. The first volume is a reprint of Domenico Guglielmini's "Della Natura de'Fiumi" the greatest work of its day. Other volumes contain the writings of Galilei, Torricelli, Manfredi, Zanotti and many other physicists and engineers of note.

For this valuable gift, which has great interest to hydrualic engineers, the Library is deeply indebted to Comm. Ing. Prof. Guadenio Fantoli of Milan. For several years, Professor Fantoli has been presenting interesting Italian publications on hydraulic engineering to the Library, of which this is the most notable.

Books Received in the Library

DER BAU DER STARRLUFTSCHIFFE. By Johannes Schwengler. Julius Springer, Berlin, 1925. Paper, 7 × 10 in., 99 pp., diagrams, 4.80 m.

A general discussion of the structural and theoretical problems involved in the design and construction of rigid airships. Written from the point of view of the structural engineer, and without any treatment of the propelling machinery. The book is apparently the pioneer work on its subject.

COMPOSITION OF TECHNICAL PAPERS. By Homer Andrew Watt and Philip B. McDonald. Second edition. McGraw-Hill Book Co., New York, 1925. Cloth, 5 × 8 in., 429 pp., $2.

A clear, direct statement of the principles of expository writing, accompanied by a selection of writings by engineers which illustrate the various types. Intended to teach engineering students to write better technical papers. The new edition has been carefully revised and new matter has been added.

DESIGN OF CRANES AND HOISTS. By Hermann Wilda. Second revised English edition. Scott, Greenwood & Son, London, 1925. (Broadway Engineering Handbooks, vol. 6.) Cloth, 5 × 8 in., 159 pp. diagrams, $2.50. (Gift of D. Van Nostrand Co., N. Y.)

A concise reference book for the designer, giving practical information on the design of the elements of lifting tackle of various types, the formulas for calculating their dimensions, and the customary constants.

EINSTEIN'S THEORY OF RELATIVITY. By Max Born. E. P. Dutton & Co., New York, 1922. Cloth 6 × 9 in., 293 pp., diagrams, portraits $5.

An elaboration of lectures given to an audience not conversant with mathematics. The book is a serious, well-executed intro-

duction to the subject, in which the origin and development of this theory from the physical theories of Einstein's predecessors are traced. The author has avoided mathematics as far as possible and has used none but very elementary formulas.

FACTORY LAY-OUT, PLANNING AND PROGRESS. By W. J. Hiscox. Isaac Pitman & Sons, London and New York, 1924. Cloth, 6 × 9 in., 184 pp., charts, $2.25.

The author, who has for many years been brought into daily contact with the problems that arise out of modern industrial conditions, here presents his views on the ethics of factory planning. A scheme of factory organization, prepared with especial reference to British conditions, is presented.

GASMASCHINEN UND OELMASCHINEN, vol. 2. By Alfred Kirschke. Second edition. Walter de Gruyter & Co., Berlin and Leipzig, 1925. Cloth, 4 × 6 in., 144 pp., illus., diagrams, 1.25 gold marks.

This volume treats briefly of the important structural details of large gas engines, oil engines, and oil and gas turbines. The first chapter discusses the generation and use of gas fuel, and the method of working and construction of large gas engines. The second and largest chapter treats of four- and two-cycle oil engines and the construction of engines for various purposes. Much of the space is given to Diesel engines. The final chapter describes the various types of gas and oil turbines.

HYDROMECHANIK. By M. Samter. Robert Kiepert, Charlottenburg, 1925. Paper, 6 × 9 in., 96 pp., 3.20 marks.

The object of this book is to make the student conversant with the most important laws of hydrostatics and hydrodynamics without too great an expenditure of time. To accomplish this, the author has abbreviated the necessary theoretical demonstrations to the briefest possible forms and has used the space thus saved for complete solutions of many examples which are important in practice and which are intended to give the young engineer the necessary accuracy and experience in calculation.

INVENTORY PRACTICE AND MATERIAL CONTROL. By Frederic W. Kilduff. McGraw-Hill Book Co., New York, 1925. Cloth, 6 × 9 in., 446 pp. illus., $5.

The first section deals with the various features connected with a physical inventory. The various necessary operations are described in detail from the planning of the inventory to its final tabulation. The second section treats of material control and describes practices intended to reduce inventories to the lowest practicable point, to eliminate losses from obsolete materials and to minimize losses through fluctuations of the market. Chapters are included on the retail method of inventory and on the relation of inventories to income and profits taxes.

JOHNSON'S MATERIALS OF CONSTRUCTION. Rewritten by M. O. Withey and James Aston; edited by E. E. Turneaure. John Wiley & Sons, New York, 1925. Cloth, 6 × 9 in., 865 pp., illus., diagrams, tables, $6.

Intended to serve both as a text and as a reference book, containing the essential information concerning the sources, manufacture or fabrication of the principal materials; selected data upon the more important physical and mechanical properties, and the influence of various factors upon them; the causes of defects and variations, and how they may be discovered, the technique of testing; and the more general uses of the different materials. This edition contains new chapters on paints and varnishes and on the constitution of some of the more important non-ferrous alloys. The chapter on the fatigue of metals has been completely revised, and minor revisions have been made throughout.

DIE KONDENSATION BEI DAMPFKRAFTMASCHINEN. By K. Hoefer. Julius Springer, Berlin, 1925. Boards, 6 × 9 in., 442 pp., illus., diagrams, tables, 22.50 gold marks.

This book owes its origin, according to the author, to the lack of any work giving a comprehensive account of the many novelties in condenser practice which have found a place in steam power plants during the past fifteen years. It is intended for use as a textbook and also as a reference book for use in practical work. The author has tried to present a succinct account of all phases of condenser practice, which will be as complete as possible and thoroughly modern in outlook. Attention is given to marine-engine practice as well as to plants on land.

THE PUBLIC AND ITS UTILITIES. By William G. Raymond. John Wiley & Sons, New York, 1925. Cloth, 6 × 9 in., 346 pp., charts, tables, $3.50.

This is an elementary discussion of the fundamental problems involved in the relations between the public and its utilities. The author endeavors to set forth the respective rights and mutual obligations of utilities and the public, with particular attention to the principles that should govern the establishment of prices, the nature and bases of proper public control and regulation, the fixing of a fair rate of return, and the determination of the fair value of the utility. The book is intended primarily for legislators, municipal officers, and members of the general public rather than for engineers.

A POPULAR HISTORY OF AMERICAN INVENTION. By Waldemar Kaempffert. Charles Scribner's Sons, New York, 1924. Cloth, 7 × 10 in., 2 vols., illus., portraits, $10.

The two attractive volumes that compose this work give the story of the invention and evolution of a number of important factors in our life. The development of our means of transportation, by railroad, electric railroad, canal and river, automobile and aircraft, is described. The evolution of modern printing and typesetting machinery, the typewriter, telegraph, telephone and radio apparatus, as well as of photography, the moving picture and the phonograph, is set forth. Another section deals with the steam engine and the generation of electricity, and a fourth with the growth of the industries—mining, lumbering and farming—that are concerned with the utilization of our material resources. The final section treats of automatic machine tools, pneumatic machines, and the machinery used in the clothing and shoe industries. The story is told in a very readable manner and well illustrated. Much attention is given to the inventors of the important machines in each group.

PRACTICAL FOREMANSHIP. By Glenn Lion Gardiner. McGraw-Hill Book Co., New York, 1925. (Industrial Education Series.) Cloth, 5 × 8 in., 191 pp., $1.75.

The purpose of this text is to present the elementary principles underlying the practice of foremanship in a form suited to the needs of foremen. Such questions as handling men, industrial good-will, employment management, the selection and training of men, wages, etc. are discussed briefly and simply. The book has been used by foremen taking extension courses in the University of Wisconsin.

PRINCIPLES OF MACHINE DESIGN. By Robert F. McKay. Longmans, Green & Co., New York; Edward Arnold & Co., London, 1924. Cloth, 6 × 9 in., 408 pp., diagrams, tables, $6.

As there are now so many diverse types of machines that it is impossible to discuss adequately the considerations and factors which influence the design of the component parts of each in a single volume, the author has limited himself to the discussion of the component parts and connections which are more or less common to all types. He has tried to develop the basic principles on which machine design rests, to show the possibilities and limitations of the devices illustrated and to give data in a convenient form for reference. The book divides broadly into three sections. The first discusses the general considerations affecting machine design, the testing and properties of the materials used, and the utilization of the data of strength tests. The second section classifies and describes the various methods of making permanent or temporary connections, while the third discusses the problem of supporting moving parts.

PROFITABLE SCIENCE IN INDUSTRY. By Dwight T. Farnham and Others. Macmillan Co., New York, 1925. Cloth, 5 × 8 in., 291 pp., illus., $3.50.

A book for business men, which calls attention to the results that have been achieved in various industries by active research work, by authors who are well known research workers in various fields. Attention is called to what has been done, to the opportunities that exist and to the organizations now actively engaged in such work. The book is readable and suggestive.

RAILROAD ACCOUNTS AND STATISTICS. By Charles E. Wermuth. Prentice-Hall, Inc., New York, 1924. Fabrikoid, 6 × 9 in., 349 pp., charts, $4.

According to the preface, this book aims to provide, in condensed form, a practical outline of present-day railroad accounting details and a description of their assembling to a completed financial statement, and also the theory and mathematics underlying the preparation of comparative statistics, with illustrations. The book is intended for railroad executives and students of railroad finance and accounting.

RAILROAD OPERATION. By Ernest Cordeal. Simmons-Boardman Publishing Co., New York, 1924. (Railwaymen's handbook series.) Cloth, 5 × 7 in., 255 pp., illus., $2.

The aim of the author is to bring to the attention of young men in railroad work certain principles of management which apply to most railroads and to show the results which have been attained by their application. The book does not attempt to outline an exact system; it is intended to induce young operating men to study their problems intensively and to assist them in the solution of the problems of policy and practice which arise in their work.

RECOVERY OF GASOLINE FROM NATURAL GAS. By George A. Burrell. Chemical Catalog Co., New York, 1925. (American Chemical Society. Monograph Series.) Cloth, 6 × 9 in., 600 pp., illus., diagrams, tables, $7.

Beginning with a history of the industry from its inception, this book then treats of the occurrence and chemistry of natural gas and the methods of testing it for gasoline. The various processes for recovering gasoline are explained and the construction and operation of the various types of plants are discussed in detail. Attention is given to depletion and also to motor fuels in general. The tables used in the industry are included. Dr. Burrell's comprehensive volume will fill a decided need.

RELATIVITY AND COMMON SENSE. By F. M. Denton. University Press, Cambridge, England, 1924. Cloth, 5 × 8 in., 279 pp., diagrams, 10s 6d.

The object of this book is to explain the meaning of the theory of relativity in reasonable terms which may be followed by any one who knows a little science and a little mathematics. The author uses a new method of attack on the difficulties that usually cause trouble to the novice, one which he hopes will enable the reader to obtain a satisfactory general understanding of the theory in spite of its difficulties.

SPECIALIZED ACCOUNTING. By George Hillis Newlove and Lester Amos Pratt. McGraw-Hill Book Co., New York, 1925. Cloth, 6 × 9 in., 475 pp., $4.

The main purpose of this book is the study of accounting principles definitely applied to various forms of business. These include cotton mills, iron foundries, cement mills, timber and logging companies, coal mines, oil wells and others. While a complete system of accounting for each business is not attempted, the accounting features and administrative problems peculiar to each are pointed out and the ways in which fundamental accounting principles may be adapted to each business are shown.

STEAM TURBINES. Including a Discussion of Mercury and Gas Turbines. By James A. Moyer. Fifth edition, revised and enlarged. John Wiley & Sons, New York, 1924. Cloth, 6 × 9 in., 515 pp., illus., diagram chart, $4.

In this work, the author has endeavored to collect the information wanted by practical engineers who are engaged in designing, operating or making steam turbines. The new edition has been thoroughly revised and modernized.

SUBJECT LIST OF THE PERIODICALS IN THE PATENT OFFICE LIBRARY. By Great Britain Patent Office Library. Patent Office, London, 1924. Paper, 4 × 7 in., 282 pp., 2s.

A catalog of the journals, transactions of societies, yearbooks, reports of permanent congresses and state and municipal departments, which are in the Library of the British Patent Office. The titles are classified under many subject headings, so that it is easy to find what periodicals are available in any given field of industry or science. Because of this arrangement, the list is also a useful guide for those who have access only to other libraries.

TABLES ANNUELLES DE CONSTANTES ET DONNÉES NUMÉRIQUES DE CHIMIE, DE PHYSIQUE ET DE TECHNOLOGIE, vol. 5, part 1. By Commission permanente du Comité international. Gauthier-Villars & Co., Paris; University of Chicago Press, Chicago, 1925. Cloth, 9 × 11 in., 804 pp., $25 (parts 1 and 2).

The first part of volume five of this important reference work is now available and the second part will appear in the near future. The volume covers the six years, 1917 to 1922, and contains the numerical constants and data relating to physics, chemistry, and allied sciences which appeared in publications during that period. The compilation is supported by subventions from many governments and scientific societies, and the volumes now issued cover the published literature since 1910. An index to the set is being prepared, which will greatly facilitate its use.

DAS TECHNISCHE EISEN. By Paul Oberhoffer. Second edition. Julius Springer, Berlin, 1925. Boards, 7 × 10 in., 598 pp., illus., diagrams tables, 31.50 gold marks.

This treatise, by the director of the Iron Institute at Aix-la-Chapelle, is a revision of his Das Schmiedbare Eisen, with extensions so that it now covers the commercial varieties of cast iron also. In general, the book is a modernization of Ledebur's classic work on the metallurgy of iron. Beginning with a section on the definition and classification of the commercial varieties of iron, the author next discusses the relations between their chemical composition and their structure. Three sections then treat of the influence of chemical composition, of temperature, and of working upon the properties of steel. The final three sections discuss malleable, gray, and chilled cast iron. The volume summarizes our knowledge of the constitution of iron and of the effects of composition, heat treatment, and mechanical treatment on its properties, in the light of recent metallographic investigations.

THOMAS' REGISTER OF AMERICAN MANUFACTURERS. 1924–1925. Thomas Publishing Co., New York, 1925. Cloth, 9 × 12 in., $15.

In plan and scope the fifteenth edition of this guide for purchasers follows its immediate predecessors, but all the information has been brought up to date. It covers all branches of industry and is the largest book in its field. In addition to the usual lists of manufacturers arranged by name and by products, it includes lists of trade names, banks, commercial organizations, trade papers, exporters, importers, shipping lines, and forwarders.

UNTERSUCHUNGEN ÜBER DIE GAS-UND ÖL-GLEICHDRUCKTURBINE. By Wilhelm Gentsch. Wilhelm Knapp, Halle (Saale), 1924. Paper, 7 × 10 in., 123 pp., tables, 5.20 m.

This is a report, in detail, of an investigation of the Semmler gas-turbine process which was made in 1904 and 1905 under the auspices of four leading German engine builders. In the Semmler process the gas is burnt at constant pressure, the products of combustion are first used to heat a boiler and later, when cooled to a workable temperature, used to drive a turbine. The book is a welcome addition to the scanty literature on continuous-combustion gas turbines, as it gives an account of practical investigations and the conclusion drawn from them.

VERZEICHNIS DER DR.-ING.-DISSERTATIONEN DER DEUTSCHEN TECHNISCHEN HOCHSCHULEN. . . . 1913–1922. By Willy B. Niemann. Robert Kiepert, Charlottenburg, 1924. Paper, 6 × 9 in., 96 pp., 6 marks.

This catalog of the dissertations submitted in fulfilment of the requirements for the degree of Doctor of Engineering continues that issued by C. Walther in 1913. Over 1600 dissertations are included, with information as to their lengths and places of publication, the schools to which they were submitted, etc. The entries are thoroughly classified and are accompanied by author and subject indexes. The book should be of value to those engaged in research.

WORKSHOP GAUGES AND MEASURING APPLIANCES. By Louis Burn. Isaac Pitman & Sons, London and New York, 1924. Cloth, 5 × 7 in., 154 pp., illus., tables, $1.50.

Describes the methods and instruments used in machine shops for measurements of various kinds. Includes chapters on marking off, the selection and care of instruments, and on limits and fits. The text is clear and concise.

THE ENGINEERING INDEX

Registered United States, Great Britain and Canada

LAST-MINUTE ADDITIONS; MAIN BODY ON PAGE 113-EI, ADVERTISING SECTION

Exigencies of publication make it necessary to put the main body of The Engineering Index into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AIRPLANES

Sikorsky. Safety Is Outstanding Feature of Sikorsky Plane Design, L. S. Gillette. Automotive Industries, vol. 52, no. 14, Apr. 2, 1925, pp. 616–618, 3 figs. Steel and duralumin construction used throughout in 12-passenger twin-engined biplane built at Roosevelt Field, L. I.; rivets and bolts used to join parts; fuselage built to give maximum passenger comfort.

AUTOMOBILE ENGINES

Andreau. The Andreau Engine (Le moteur Andreau), Andreau. Technique Automobile et Aérienne, vol. 15, no. 127, 1924, pp. 97–111, 24 figs.; also description by E. H. Weiss, in Nature (Paris), no. 2651, Jan. 24, 1925, pp. 55–59, 8 figs.; and (translation) in Mech. Eng., vol. 47, no. 4, Apr. 1925, pp. 292–293, 2 figs. Essential feature of engine is that it has substituted for older method of operation a simple mechanical combination which permits making length of piston stroke different in different parts of cycle and, in particular, makes exhaust stroke longer than intake stroke; this insures perfect withdrawal of exhaust gases from explosion chamber and longer duration of expansion than of compression, which in its turn produces material increase in work delivered by engine; results of tests.

AUTOMOBILE MANUFACTURING PLANTS

Continuous Production. Some Notes on British Methods of Continuous Production, Automobile Engr., vol. 15, no. 200, Mar. 1925, pp. 85–93, 22 figs. Keynote throughout paper is "flow principle," and several methods of regularization to obtain that flow are described; chief instrument for regularization of machine shop is mechanical movement of workpiece under time control; describes machines built to attain degree of mechanization which has not to author's knowledge been achieved before.

BOILER FURNACES

Arches. A Suspended Furnace Arch. Engineer, vol. 139, no. 3613, Mar. 27, 1925, p. 361, 3 figs. Describes Liptack furnace arch which, besides possessing merit of practically unlimited width, has advantage that it is flat; result is that heat which it radiates back on to fire is evenly distributed across grate and ignition of fuel is well balanced throughout fire.

BOILERS

Characteristics. The Characteristics of Steam Boilers, R. H. Parsons. Engineering, vol. 119, no. 3091, Mar. 27, 1925, pp. 379–381, 5 figs. Interesting facts relating to performance tests of different types of boilers are shown graphically, indicating general nature of performance to be expected from various types of boilers operated at different loads.

BOILERS, WATER-TUBE

High-Pressure. Super-Pressure Steam Generation by Means of the Atmos Boiler (Höchstdruckdampferzeugung durch Atmoskessel), E. Josse. Zeit. des Vereines deutscher Ingenieure, vol. 69, no. 7, Feb. 14, 1925, pp. 169–173, 6 figs. With Atmos boiler, designed by J. V. Blomquist, new means of generating super-pressure steam have been developed, which are considered in light of practical and experimental results.

Large. The Large Water-Tube Boiler, P. W. Robson. Engineering, vol. 119, no. 3090, Mar. 20, 1925, p. 360. General aspects of problem; technical problems of large boiler; types suitable for large units; pulverized fuel. Paper read before Instn. Civ. Engrs.

CAMS

Designing. Designing of Cams Is Much Simplified by Graphical Method, W. D. Appel. Automotive Industries, vol. 52, no. 12, Mar. 19, 1925, pp. 544–546, 4 figs. Describes simple method of designing cams which commends itself because of ease and rapidity with which desired results are obtained; it does not involve use of mathematical formulas.

CENTRAL STATIONS

Superpower, Fall River, Mass. "Somerset," Another Step Toward Super-Power. Power Plant Eng., vol. 29, no. 7, Apr. 1, 1925, pp. 368–376, 6 figs. New base-load station for three public utilities on Taunton River, near Fall River, Mass.; initial installation consists of one 32,000-kw. turbo-generator unit with three 1492-hp. Stirling boilers; oil is used at present time as fuel, but provision has been made so that pulverized coal can be burned whenever it becomes desirable. Tabular data of equipment.

COST ACCOUNTING

Production Scheduling for. A Production Schedule for Factory Accounting Work, D. Ross. Mgt. & Admin., vol. 9, no. 4, Apr. 1925, pp. 363–364, 1 fig. Shows how system of time schedules for accounting department has been operated successfully and gives results of scheduling.

CUTTING TOOLS

Durability-Speed Curves. Experiments with Lathe Tools on Fine Cuts, and Some Physical Properties of the Tool Steels and Metal Operated Upon, Dempster Smith and A. Leigh. Engineering, vol. 119, no. 3090, Mar. 20, 1925, pp. 364–366, 13 figs. Experiments were made with object of obtaining characteristic durability-speed curves for carbon and high-speed steel tools, and with object of linking together results obtained with coarse and extremely fine cuts.

Improved Form. Investigations in Turning (Die Ungersuchung der Dreharbeit), H. Klopstock. Zeit. des Vereines deutscher Ingenieure, vol. 69, nos. 8 and 10, Feb. 21 and Mar. 7, 1925, pp. 215–221 and 311–314, 47 figs. Account of experiments conducted in machine-tool laboratory of Berlin Technical High School; cutting tests proper were preceded by study of lathe and instruments used; as results of main tests, new form of tool has been designed which, author claims, permits higher cutting speed and larger chip section than is practicable with standard tools now used; results of tests in various German railway shops, in which relative life of cutting edges of new and old tools under same conditions was compared; it is claimed that an average, production can be increased about 30 per cent by means of new tool.

ELECTRIC LOCOMOTIVES

Motor-Generator. 22,000-Volt Motor Generator Locomotives. Engineer, vol. 139, no. 3612, Mar. 20, 1925, pp. 334–335, 8 figs. Details of engines for Detroit and Ironton Railway; principal reasons for choosing motor-generator locomotives.

HYDRAULIC TURBINES

Experimental Research. Experimental Research in Hydroelectric Power Engineering (Die experimentelle Forschung im Wasserkraftfach), D. Thoma. Zeit. des Vereines deutscher Ingenieure, vol. 69, no. 11, Mar. 14, 1925, no. 329–334, 9 figs. Development of experimental work in Germany; systematic tests were begun in 1880; at present there are 13 experimental stations; principle of superposition of small variations; turbine blade surfaces can be represented with parameters by means of equations; dimensionless coefficients to represent experimental results; results with propeller turbines; problem of cavitation; law of similarity of cavitation; results of cavitation tests; other methods and tasks; hydraulic model tests; progress in theoretical and experimental methods.

HYDROELECTRIC PLANTS

Switzerland. The Chancy-Pougny Hydro-electric Power Station. Engineer, vol. 139, no. 3612, Mar. 20, 1925, pp. 321–324 and 328, 13 figs. Details of station nearing completion on Rhone, short distance below Geneva; power is derived from river by means of barrage; total horsepower, which will be available in form of electrical energy, will be 38,000, and it is anticipated that station will have annual output of from 130,000,000 to 160,000,000 kw-hr.

INDUSTRIAL MANAGEMENT

Executive Control Chart. Control Chart for the Chief Executive, W. Clark. Iron Age, vol. 115, no. 12, Mar. 19, 1925, pp. 828–831, 1 fig. Presents chart prepared for chief executive of manufacturing company which frees him of detail and permits of concentration on control; check kept on quality of product and service; work ahead of plant definitely known; sales quotas compared with orders received; costs and other operating data charted; information relating to employees included.

Obsolescence, Handling of. The Handling of Obsolescence by Manufacturers. Am. Mach., vol. 62, no. 15, Apr. 9, 1925, p. 583. Suggestions taken from experience of considerable number of representative manufacturing companies; salvage departments; example of practice.

Production Lots, Determining Proper Size of. Method of Finding Minimum-Cost Quantity in Manufacturing, Ralph C. Davis. Mgt. & Admin., vol. 9, no. 4, Apr. 1925, pp. 353–356, 1 fig. Formulas for size of production lots; rational method of determining proper quantity to manufacture and to carry in stock to give least unit cost.

Stock-Room Arrangement. Handling Cost Reduced by Rearranging Stock Room. Iron Age, vol. 115, no. 15, Apr. 9, 1925, pp. 1056–1057, 2 figs. Labor savings in cost of handling bar and sheet stock have accompanied improved arrangement of new stock room of Hall-Scott Motor Car Co., Berkeley, Cal.; centrally located building with automatic machine and stamping departments in adjoining bays.

LOCOMOTIVES

Diesel-Electric. An Italian Double-ended Diesel-Electric Locomotive. Engineer, vol. 139, no. 3613, Mar. 27, 1925, p. 358, 1 fig. Locomotive has electric drive which gives about 70 per cent efficiency between motor shaft and rails; this drive was adopted because it enabled electric motor vehicle on train to be driven from Diesel when heavier trains were necessary.

Lentz Hydraulic Transmission. The Lentz Variable Hydraulic Transmission Gear. Engineering, vol. 119, no. 3090, Mar. 20, 1925, pp. 350–351, 7 figs. partly on p. 354. First infinitely variable Lentz patent hydraulic transmission for locomotives built in England; gear is type utilizing oil as medium of transmission.

MACHINE SHOPS

Equipment, Profits from Modern. Net Profits from Modern Equipment, F. A. Scott. Iron Age, vol. 115, no. 14, Apr. 2, 1925, pp. 957–961, 7 figs. Lowering production cost to get lower selling price and, in turn, increased consumption and better net profits; possibilities of increased net profits through up-to-date machinery; examples of progressive policy.

MACHINING METHODS

Gang Fixtures for Quantity Production. Gang Fixtures for Quantity Production, F. L. Libgotte. Machy. (N. Y.), vol. 31, no. 8, Apr. 1925, pp. 625–629, 13 figs. Describes and illustrates fixtures used in machining piece from half-hard drawn steel.

MATERIALS HANDLING

Trucking Practice. Material Handling Pay-Roll Reduced 75%, M. C. Maxwell. Factory, vol. 34, no. 4, Apr. 1925, pp. 594–598, 17 figs. Two fundamentals of trucking practice which author has learned are: adapt equipment to work it must do; and schedule day's work of each truck; shows how these two essentials were accomplished.

MOTOR TRUCKS

General Motors Co. New G. M. C. Trucks Have Four-Wheel Brakes as Standard Equipment, W. L. Carver. Automotive Industries, vol. 52, no. 14, Apr. 2, 1925, pp. 610–613, 7 figs. Many parts are interchangeable between 1 and 1½-ton models; pneumatic cord tires are used to permit high speeds.

OIL ENGINES

Solid-Injection. Test of the Hesselman Solid-Injection Oil Engine, E. Lundgren. Power, vol. 61, no. 14, Apr. 7, 1925, p. 523, 2 figs. 4-stroke-cycle engine, built by Bofors Steel Works, has 4 cylinders, liners of which are inserted in common water jacket forming rigid casting or block; comprehensive tests, carried out by Prof. E. Hubendici, of Roy. Tech. Univ. of Stockholm, Sweden, gave excellent results.

PLANERS

Cincinnati Hypro. Cincinnati "Hypro" Planer. Machy. (N. Y.), vol. 31, no. 8, Apr. 1925, pp. 655–656, 2 figs. Selective dial feeds are furnished for all heads; dials are graduated in sixty-fourths of an inch; reading can be determined from front of machine; bed is double the length of table so that table never overhangs.

PULVERIZED COAL

Textile Mills. New England Textile Plant Operates on Powdered Fuel. Power, vol. 61, no. 13, Mar. 31, 1925, pp. 482–484, 4 figs. Installation of Uxbridge Worsted Co.; unit pulverizers used with horizontal return-tubular boilers; operation flexible and efficient.

STEAM POWER PLANTS

Economical Operating Methods. New Methods Cut Power Plant Costs, C. E. Killinger. Mgt. & Admin., vol. 9, no. 4, Apr. 1925, pp. 325–328, 3 figs. Savings of $67,200 a year made by improved operation of power plant of Willys-Morrow Co.

Limiting Possibilities of. The Limiting Possibilities in Steam Plants, A. L. Mellanby and Wm. Kerr. North-East Coast Instn. Engrs. & Shipbldrs.—advance paper, no. 2696T, for mtg., Feb. 27, 1925, 22 pp., 11 figs. Examines available and fundamental facts in search for real upper limits to sequence of operations in steam plants; discusses temperature limits, pressure, and number and extent of reheating stages; progressive determination of essential limits leading by steps to establishment of limiting and explicit cycle of operations. See also Engineering, vol. 119, nos. 3088, 3089 and 3090, Mar. 6, 13 and 20, 1925, pp. 301–303, 334–336 and 336–367, 11 figs.; and editorial review in no. 2088, Mar. 6, pp. 294–295.

STEEL CASTINGS

Open-Hearth. Special Open-Hearth Steel Castings, S. H. Bunnell. Iron Age, vol. 115, no. 13, Mar. 26, 1925, pp. 901–903, 6 figs. Intricate products at low cost; high-grade steel from low-grade scrap made in Bosshardt furnace in Germany; furnace is of open-hearth type, with usual reversible or regenerative checker work, heated by combustion of producer gas, taken directly from small special gas-producing chambers built on two ends of furnace.

X-Ray Investigation. X-Ray Investigation of Steel Castings for Advanced Steam Conditions, F. H. Morehead. Power, vol. 61, no. 14, Apr. 7, 1925, pp. 520–522, 3 figs. Account of investigation made by Ordnance Testing Laboratory at Watertown Arsenal; Coolidge tube of usual medical type, except for size, was used; sample tee castings were produced and submitted to laboratory for investigation; most careful check failed to disclose any surface indication of hidden defects, giving positive proof that test-bar data could not be taken as representing casting conditions.

WELDING

Cast Iron to Steel. Cast Iron Valve Heads Can Be Welded to Steel Stems at Rate of 400 per Hour, H. Chase. Automotive Industries, vol. 52, no. 12, Mar. 19, 1925, pp. 533–534, 5 figs. New Hall process minimizes machining operations; no drilling or threading required; shank is upset during butt welding so that strength of joint is greater than that of stem.

MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

Spring Meeting Papers

This supplement to the May issue of MECHANICAL ENGINEERING presents a number of the papers that will be read at the meeting and brings information about others that are available in pamphlet form to those who request them. It is the sincere hope of the Committee on Meetings and Program and the Committee on Publications that these papers, published as they are well in advance of the meeting, will arouse discussion at the meeting that will contribute equally with them to the value of the Society's published records.

Be sure to bring this copy to the Meeting

MAY 1925

THE MONTHLY JOURNAL PUBLISHED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Mechanical Engineering

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Price 60 Cents a Copy, $5.00 a year: to Members and Affiliates, 50 Cents a Copy, $4.00 a year. Postage to Canada, 75 Cents Additional; to Foreign Countries $1.50 Additional. Changes of address should be sent to the Society Headquarters.

The Purpose of This Supplement

THIS special supplement to the May issue of MECHANICAL ENGINEERING brings advance information about the Program of the Milwaukee Spring Meeting of the A.S.M.E., together with the text of a number of complete papers and synopses of others that are available in pamphlet form. Copies of the latter may be obtained by filling in the form on page 447. This supplement, however, should be brought to the Meeting, as copies of the papers appearing in it will not be available for free distribution. However, additional copies of the supplement may be purchased at the Meeting.

It is the purpose of this supplement to make available to the members of the A.S.M.E. information regarding the papers that are to be presented, so that discussion at the Meeting will be well considered and thoughtfully prepared.

As it is the purpose of a meeting of the Society to secure the greatest possible participation by all of those who attend, it is highly desirable that members have advance information as to the subject-matter of the papers that are to be read at the meeting. It is a waste of valuable time for an author to read a technical paper from beginning to end at a meeting, for the audience is seldom able to evaluate statements that are made and compare them with their own experience. Further, there is a limit to the amount of time during which interest in the presentation of a technical paper can be maintained.

It has been the effort of the Committee on Meetings and Program to stimulate discussion at the meetings of the Society, knowing that a spirited discussion insures an interesting meeting. Discussion greatly strengthens the permanent value of the papers presented at the meeting. A paper which has been subjected to the fire of public criticism or warmed by the addition of corroboratory information is, when properly recorded, of much greater value as a part of the permanent literature of mechanical engineering than a spiritless or an uncriticized contribution. In some cases the discussion may be of even greater value than the paper. From its value in instilling interest in the meeting and from its effect on the record of the meeting, discussion is therefore vitally essential. The Committee on Meetings and Program and the Committee on Publications have coöperated in this procedure for presenting and issuing papers for the Milwaukee Spring Meeting.

The Milwaukee Spring Meeting

MILWAUKEE is the place for the 1925 Spring Meeting of The American Society of Mechanical Engineers. The dates are from May 18 through 21, and the headquarters will be the Hotel Pfister. The program on the opposite page includes the technical sessions and a mention of the interesting entertainments and excursions which the Milwaukee Committee is planning. The current issues of the *A.S.M.E. News* are giving particulars of the many interesting events that are to be held during the four days of the meeting.

Milwaukee is a city of diversified industries, and members engaged in all phases of mechanical engineering will find much of interest and value in the program.

The American Society of Refrigerating Engineers will hold a meeting in Milwaukee simultaneously with that of the A.S.M.E., and on the afternoon of Thursday, May 21, there will be a joint hearing on the Test Code for Refrigerating Apparatus.

MECHANICAL ENGINEERING

Volume 47 May, 1925 No. 5, Section 2

Tentative Spring Meeting Program

Hotel Pfister—Milwaukee, May 18–21, 1925

Monday, May 18

Morning:
Meeting of A.S.M.E. Council
Local Sections Conference

Afternoon:
Business Meeting of Society
Meeting of A.S.M.E Council
Boiler Code Public Hearing
Excursions: Sewage Disposal Plant; Palmolive Company; Phoenix Hosiery Company

Evening:
Reception

Tuesday Morning, May 19, 9:30 A.M.

Machine Shop

Recent Investigations in Turning and Planing and a New Form of Cutting Tool, H. KLOPSTOCK.
A Code of Design for Mechanical Springs, J. K. WOOD.
Defects in Large Forgings, J. FLETCHER HARPER.

Hydroelectric

The Parallel Operation of Hydro and Steam Plants, F. A. ALLNER.
Mechanical Features Affecting the Reliable and Economical Operation of Hydroelectric Plants, E. A. DOW.
Mechanical Problems of Hydraulic-Turbine Design, WM. M. WHITE.

Forest Products

A New Era in Forestry, H. F. WEISS.
Standardization of Grading Rules for Hardwood Lumber, A. T. UPSON.

Pulverized Coal

A Microscopic Study of Pulverized Coal, L. V. ANDREWS.
Boiler Furnaces for Pulverized Coal, A. G. CHRISTIE.
Radiation in the Pulverized-Fuel Furnace, W. J. WOHLENBERG and D. G. MORROW.

Tuesday Afternoon

Excursions

Allis-Chalmers Mfg. Co.
Eline's, Inc. (Chocolate) powdered-fuel plant.
Robt. A. Johnston Co., manufacturers of candies, crackers and cookies.
Kearney & Trecker Company.

Student Branch Conference

Tuesday Evening

Musicale

Visit to Central Continuation School

Milwaukee Session

The Activated-Sludge Sewage-Disposal Plant at Milwaukee, JOHN A. WILSON.
Critical Study of Heat and Power Requirements of Sewage-Disposal Plants, ROBT. CRAMER.
Duty Tests of Vertical Triple-Expansion Pumping Engines, Milwaukee, Wis., CHARLES A. CAHILL.
The Economical Advantage of Cities Having Diversified Industries, (Author to be announced.)

Wednesday Morning, May 20, 9:30 A.M.

Materials Handling

Formulas for Computing the Economies of Labor-Saving Equipment, J. A. SHEPARD and G. E. HAGEMANN.
An Application of the Formulas for Computing Economies of Labor-Saving Equipment, GEO. LANGFORD, JR.
Labor-Saving Equipment in Road Construction, E. H. LICHTENBERG and J. A. SHEPARD.
Economic Efficiency of the Full-Automatic Turret Lathe in Comparison with the Semi-Turret Lathe, R. J. WADD.

Industrial Power

Torsional Vibrations and Critical Speeds of Shafts, A. LACK and C. B. JAHNKE.
Tests of a Uniflow Engine, G. H. BARRUS.

National Defense

On the invitation of the War Department and the A.S.M.E., manufacturers of Wisconsin will meet to go over the industrial-preparedness plans in Wisconsin based on the allocations of materials to be manufactured in that district.

Materials

The X-Ray Examination of Steel Castings, I. E. MOULTROP and E. W. NORRIS.
Aluminum and Its Light Alloys, R. L. STREETER and P. V. FARAGHER.
Stress Concentration Produced by Holes and Fillets, S. TIMOSHENKO and W. DIETZ.

Wednesday, Afternoon

Excursions

Vilter Mfg. Co.
Riverside Pumping Station.
Falk Corporation.

Public Hearing, Power Test Codes

Test Code for Centrifugal and Rotary Pumps.
Test Code for Reciprocating Steam-Driven Displacement Pumps.

Wednesday Evening

Dinner

Public Meeting

Assistant Secretary of War Davis as principal speaker.

Thursday Morning, May 21, 9:30 A.M.

Steam Power

A Review of Steam-Turbine Development, HANS DAHLSTRAND.
Rational Design of Covering for Pipes Carrying Steam up to 800 Deg. Fahr., W. A. CARTER and E. T. COPE.
Lake Waters for Condensers, A. G. CHRISTIE.
Analysis of Power-Plant Performance Based on the Second Law of Thermodynamics, W. L. DEBAUFRE.
Comparison of Actual Performance and Theoretical Possibilities of the Lakeside Station, M. K. DREWRY.

Management

Steel-Foundry Management, R. A. BULL.
Management of Gray-Iron Foundries, G. P. FISHER.
Report of Committee on Elimination of Unnecessary Fatigue, GEO. H. SHEPARD.

Apprenticeship

A National Apprenticeship Program, HAROLD S. FALK.
Milwaukee District Apprenticeship Scheme (Author to be announced).

Railroad

Factors Concerning the Economics of Shopping Steam Locomotives, L. K. SILLCOX.
Freight-Car Maintenance, C. G. JUNEAU.

Thursday Afternoon

Excursions

Lakeside Power Station.
Nordberg Mfg. Company.

Public Hearing with A.S.R.E.

Test Code for Refrigerating Systems.

The X-Ray Examination of Steel Castings

By I. E. MOULTROP[1] AND E. W. NORRIS,[2] BOSTON, MASS.

THE rapid development of power-station design toward higher pressures and temperatures necessitates a corresponding improvement in the qualities of the materials used for equipment. The physical properties must be better, and these properties must be realized not only in the laboratory but also in the commercial product. We can no longer rely on a conservative factor of safety to counteract possible flaws, for many modern designs prohibit large excesses of metal, and experience indicates that flaws involve not only an initial weakness but also a tendency toward deterioration during service. It is therefore necessary to eliminate flaws rather than to provide excess metal to compensate for them.

This situation is by no means new. The history of materials manufacture is a record of laboratory study and the gradual application of laboratory methods to commercial processes. This paper discusses one of the latest of these methods to be thus applied, that is, the use of X-rays.

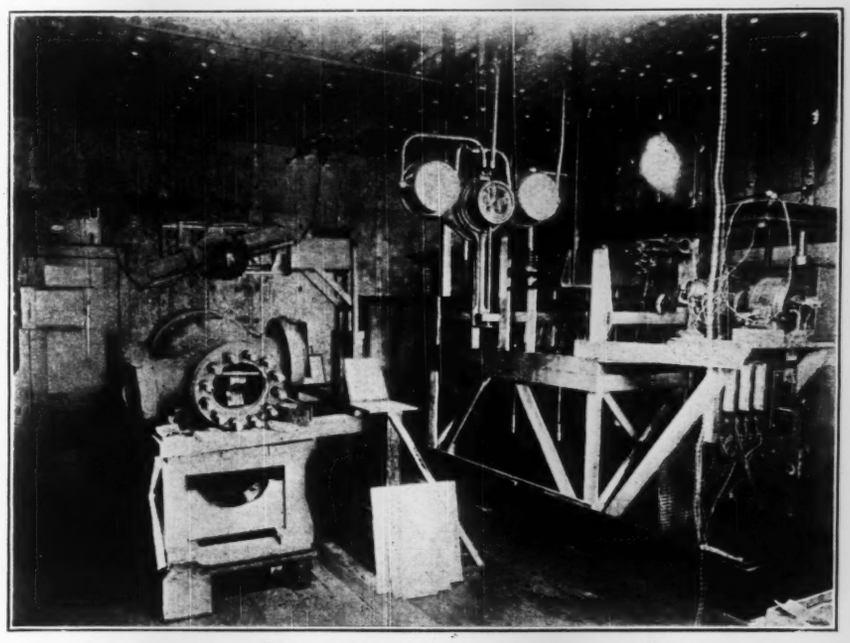

FIG. 1 THE X-RAY ROOM

DEVELOPMENT OF X-RAY EXAMINATION

The examination of materials by X-rays was suggested in the very early days of X-ray work. It is only recently, however, that apparatus and technique have been developed to a point where satisfactory commercial work can be undertaken. Probably the first successful work of this nature was that done by Dr. Davey of the General Electric Company in 1915. At that time steel castings for various purposes were examined, the development of the Coolidge tube having made possible penetration of castings up to a considerable thickness.

A certain amount of work was done during the war in inspecting munitions of various kinds. As a result of the war work, the Watertown Arsenal at Watertown, Mass., under the direction of Col. T. C. Dickson, has developed the technique of X-ray photography of metals, and especially of steel castings, in conjunction with a corresponding development of foundry practice. Their efforts have been most successful and many difficult castings have been made commercially possible by the insight into their quality obtained through X-ray work.

The X-rays do not possess any peculiar property that improves a given material, but they furnish a means by which its innermost structure may be examined and, to a considerable degree, analyzed without damage. The value of such an examination is twofold: the soundness of the material can be tested, and the location and character of flaws can be determined. The causes of flaws can be suggested by checking against the details of the processes of manufacture. In this way a foundation is laid for the elimination of flaws by the improvement of manufacturing processes brought under suspicion.

At the present time the most important metallurgical application of X-ray methods is in the study of steel castings. Careful work along this line enables the foundry to turn out work that compares favorably with that of the forge. The advantages to be thus obtained are obvious and amply warrant the most careful consideration.

X-RAYS AND X-RAY APPARATUS

X-rays do not differ fundamentally from light rays. They are waves in the same medium and of the same character as light waves. They are, however, of very much shorter wave length and have the power of penetrating substances opaque to ordinary light waves, and also of impressing an image on a photographic plate.

X-rays are generated in vacuum tubes similar to, but very much larger than, the now familiar radio tube. A small filament at one end of the tube is heated by an electric current, and a high potential is impressed between this heated filament and a target plate. The heated filament in the vacuum tube gives off a large quantity of electrically charged particles which are directed against the target at enormous velocities by the electric potential. These electrically charged particles do not constitute X-rays, but when they strike the target their energy is released and is transformed in some way into the vibrations radiated by the target as X-rays.

The penetrating power of the X-rays generated by a tube depends very largely upon the velocity at which the charged particles are projected against the target; which again depends on the voltage between the filament and the target plate. This voltage varies from some 20,000 or 30,000 upward. For the examination of heavy castings very high voltages must be resorted to in order to obtain sufficient penetrating power to produce satisfactory photographs or "radiographs." At the present time, the commercial limit is about 250,000 volts, which gives a maximum penetration of approximately 3 in. of steel. Under favorable conditions this may be extended to 4 in. This suffices for a large part of the work required, but falls short of the penetration needed for the heavy flanges, etc. on ultra-high-pressure equipment. It is estimated that an

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operating voltage of 600,000 can be successfully applied, which would give a penetration of approximately 6 in. Unfortunately, up to the present time means have not been available to carry on the research necessary to develop this equipment.

X-rays have the peculiar quality of setting up secondary radiation

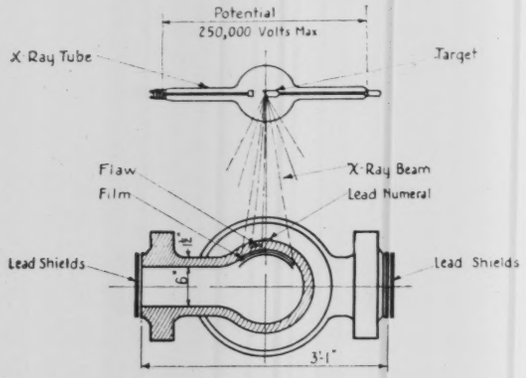

FIG. 2 SET-UP FOR X-RAY PICTURE

in almost all substances. Thus, when a metal plate is penetrated by X-rays, secondary radiation is generated by the metal itself, which glows, as it were, with an invisible radiance. This radiation is very similar to the X-rays generated by the tube and is capable of impressing a photograph plate. It is frequently a source of difficulty, as special care is required to filter out the indirect radiation so as not to blur the shadows cast by the direct radiation from the tube.

In making an X-ray photograph or radiograph of an object, the X-ray tube is set up over the portion to be examined and a photographic plate or film is placed immediately beneath the material. The rays penetrate the material and impress the plate. Various thicknesses or densities of material absorb varying amounts of rays, or in other words, cast shadows of varying density on the plate. These form an image which may be made visible by developing the plate in the usual way. Obviously, therefore, the radiograph is a shadow picture of the material being studied. The features shown are approximately full size, and the depth of tone of the negative shows the comparative density or thickness of the material. A hole or thin spot allows more rays to reach the plate, and appears as a dark outline on the negative and vice versa. The method is extremely sensitive, for variations of density or thickness of 2 per cent can be definitely detected. The ordinary flaws of commercial castings that are of enough importance to warrant consideration are equivalent to variations of ten or twenty per cent or more. These can therefore be detected and their importance weighed with a satisfactory degree of accuracy.

The apparatus for X-ray work (Fig. 1) is comparatively simple. The tube itself is supported on a stand which is adjustable for various positions. Flexible lead wires run to the power source with a milliammeter to indicate the current flow through the tube. Power is supplied by a step-up transformer and rectified by a commutator driven by a synchronous motor. The commutator consists of a series of revolving arms which just clear current collectors in the form of circular arcs. These are so located that a proper path is provided for the current to maintain a direct pulsating voltage across the terminals as the commutator revolves.

As X-rays are very injurious to human tissue when subject to frequent exposure, the X-ray equipment is housed in a room lined with quarter-inch lead. The control panel is located outside the room. To give the operator a view of the tube and other equipment a lead-lined periscope is provided which takes advantage of the fact that ordinary light rays are reflected by mirrors that absorb or transmit the X-rays.

When a casting is to be examined, a careful study is made to determine the critical parts. Then the best method of radiographing

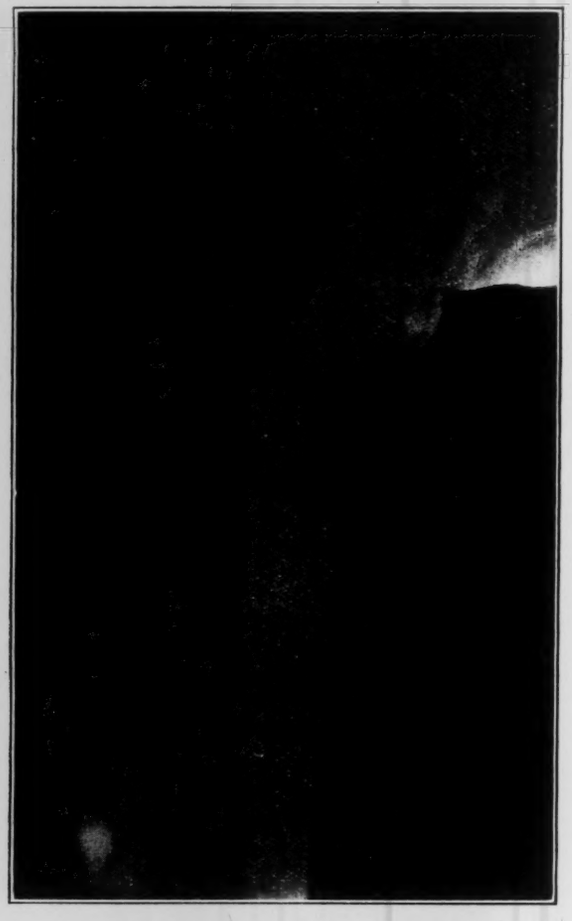

FIG. 3 RADIOGRAPH OF GAS POCKETS, FULL SIZE

FIG. 4 RADIOGRAPH OF SAND INCLUSIONS, FULL SIZE

these is decided on. The parts are then numbered plainly, and the casting is photographed in the ordinary way to locate the numbered sections for future reference.

In taking the X-ray pictures the casting is placed so that the desired area is directly in line with the path of the X-rays from the tube, which is located above or at one side. See Fig. 2. A lead

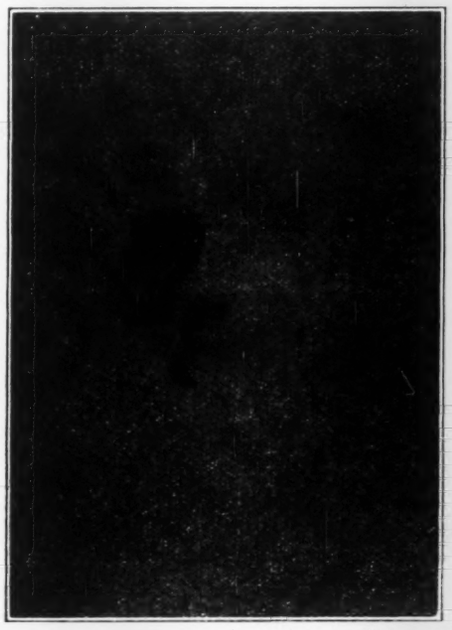

FIG. 5 RADIOGRAPH OF SHRINKAGE FLAWS, SLIGHTLY REDUCED

FIG. 6 RADIOGRAPH OF PIPE, SLIGHTLY REDUCED

FIG. 7 RADIOGRAPH OF PIPE, SLIGHTLY REDUCED

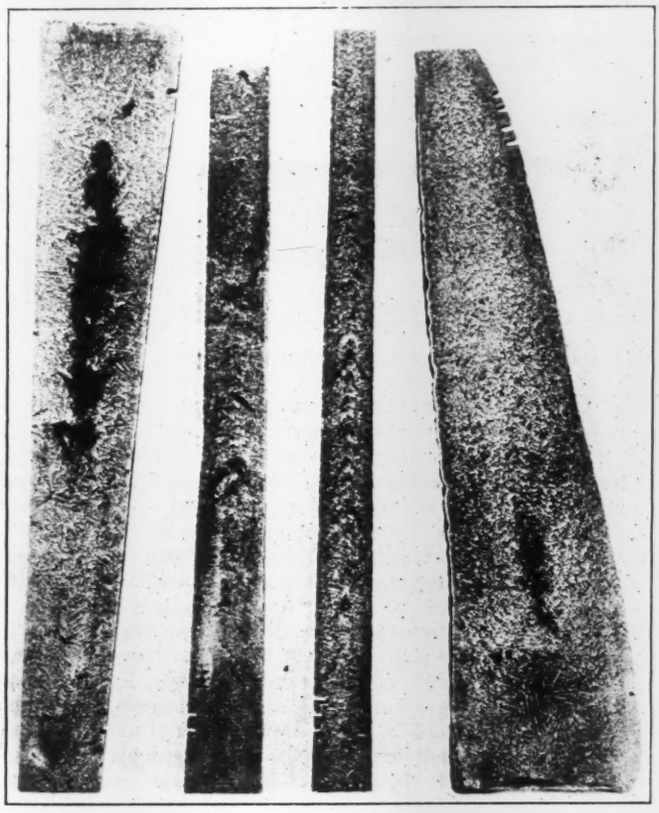

FIG. 8 ARROWHEAD FLAWS (ETCHED SECTION), SLIGHTLY REDUCED

number is placed on the metal over the area number to identify the radiograph and a plate or film is placed under the metal and as close to it as possible. The plate is backed with lead to prevent the secondary radiations from reaching the sensitized surface. In some cases a thin lead screen is placed in front of the plate or film to filter out scattered radiations.

The exposure may be anything up to thirty minutes or more, depending on the thickness of metal to be penetrated. During long exposures it is necessary to stop occasionally to allow the tube to cool down. This frequently doubles the actual time required.

If the section of metal is uniform in thickness the penetration is correspondingly uniform. Where there is a marked change, as at a rib or a flange, there is a tendency to overexpose the thin section in order to penetrate the heavy section. This is counteracted by covering the thin part with a light screen of lead. This protects the thin section and allows much better penetration of the thick section. There is no chance of confusing this "mask" with a flaw as the edge is cut clear and sharp—quite different from the jagged outline of a crack.

The outline of flaws as shown on the radiograph is an exact reproduction of the flaw in the metal, except that there is a certain amount of parallax. This is due to the projection of the rays from a center on the target of the X-ray tube to the photographic plate or film. This is often exaggerated by the use of a film curved to fit the interior of a cylindrical surface.

FIG. 9 RADIOGRAPH OF CRACKS, SLIGHTLY REDUCED

FLAWS OBSERVABLE

The defects observable in steel castings as determined by the inspection and checking of hundreds of specimens may be grouped under a few general types:

Gas pockets (Fig. 3) are usually clearly defined spherical cavities, though they are often irregular in shape with a rounded outline. They show on the radiograph as rounded spots. Sometimes the gas has moved through the metal leaving a bore like a worm hole which shows a picture rather like a small comet. These cavities may be caused by failure to remove the gas from the metal before pouring; or they may come from sand or dirt in the mold, which generates gas under the high temperatures of the steel. Sometimes the gas pockets are caused by steam from a damp mold.

Sand may be washed from a poorly rammed mold and be covered by the metal. These sand inclusions (Fig. 4) sometimes represent a considerable volume. They may be invisible from the surface of the casting. In the radiograph they show as cloudy areas of irregular outline. When the sand is reasonably free from dirt or binding compound no gas is formed, but the sand inclusions represent areas subject to extremely rapid erosion when the surface metal has been penetrated.

Pipes and voids caused by the shrinkage of the metal during solidification are the most common fault to be found in steel castings. (Fig. 6.) In many cases these flaws are not serious but in others they are extremely so. (Fig. 7.) As the metal in a mold cools it shrinks. The surfaces solidify and tend to pull away from the interior which is still viscous. The gates and risers form reservoirs of metal that remain molten and feed in additional metal during the shrinkage period of the main parts. If this feeding is complete the result is a sound casting; but frequently the flow of metal is retarded and the more remote sections shrink away from the core, leaving a spongy section between two sound walls. (Fig. 8.) This is usually not serious, as the factor of safety is ample to take care of the weakness of the core. It sometimes happens, however, that gas is forced into this spongy metal, exaggerating its weakness. Again, the secondary strains of cooling set up forces that may produce subsurface cracks which are a source of danger whenever the casting is placed in severe service. On the radiograph the spongy shrinkage voids show as fernlike patterns. These develop into "stream lines" when the metal has a well-defined core, and into jagged lines when cracks are formed.

Cracks are probably the most dangerous fault that must be detected, for they have the well-known tendency to increase during service. Cracks are clearly defined on a radiograph when the rays pass through the metal in the plane of the crack (Fig. 9). When the rays strike through obliquely, the image becomes hazy and may be altogether lost. For this reason, when cracks are suspected, it is desirable to take a series of radiographs at varying angles so as to detect cracks running on different slopes.

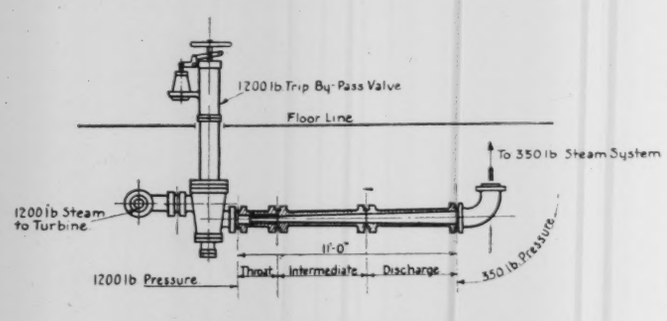

FIG. 10 ARRANGEMENT OF NOZZLE

WEYMOUTH POWER STATION WORK

The work covered by this paper was undertaken in connection with the construction of the Weymouth Power Station of the Edison Electric Illuminating Company of Boston. Part of the steam-power generating equipment at this plant operates at 1200 lb. pressure. This is the first commercial installation at so high a pressure and it was decided to take the precaution, unique in power-plant engineering, of applying X-rays to the inspection of the materials involved.

In examining the equipment careful consideration was given to the general features of the problem before any specialized work was begun. The high-pressure feedwater lines were considered as presenting no problems that have not already been solved in connection with high-pressure hydraulic work. It was therefore deemed unnecessary to use X-ray examination in connection with these. The steam fittings, however, presented the double problem of high pressures and temperatures, with the characteristic of high-pressure steam to increase inherent flaws during service.

The materials selected for high-pressure steam service were forged and cast steel and monel metal. The monel metal used as valve trimming, etc. is not subject to sufficiently critical mechanical stresses to warrant its special examination. Steel forgings have proven so reliable in actual service that the routine tests and analyses are considered entirely satisfactory proof of quality. Steel castings, however, have occasionally shown flaws which could not be detected by any of the ordinary inspection methods, and it was therefore decided to use X-ray photographs as a means of insuring the desired quality of product.

The castings for this work are all special; it was therefore impossible to use the X-ray examination as preliminary test of foundry practice, but the importance of the castings fully justified the expense of individual radiographic tests.

All examinations were made at the Watertown Arsenal. The X-ray laboratory is under the direction of Dr. Lester, to whom the authors are indebted for much of the technical data presented.

In general the castings were examined in the rough so as to avoid doing any machine work on castings which might be rejected. After examination, castings were divided into numbered areas chosen so as to cover the critical parts, as already described. For instance, valve bodies were examined with great care in the neighborhood of the flanges, to determine the soundness of the metal at these points of concentrated stresses. Radiographs were then made covering these areas and the results were carefully studied in connection with the casting itself. Slight shadows on the radiographs were frequently found to be caused by surface irregularities on the casting. For instance, a line of pattern numbers slightly raised above the surface of a casting were very clearly shown on the corresponding radiograph.

In order to check the interpretation of the X-ray work a condemned casting showing a large number of characteristic flaws was carefully cut into sections so as to expose the flaws, and these were then etched and compared with the radiographic negatives. Chemical and physical tests were also performed as a check on the work and it was found that in every case the original interpretation of the radiograph was fully borne out by the character of the casting at the point of examination.

In connection with this work a special effort was made to lay the results of the examinations before the manufacturer producing the casting so that through coöperation the occasional flaws discovered could be eliminated.

EXAMPLES OF WORK

Turning to actual examples of the castings examined, perhaps the most interesting is a nozzle section. This proved to be seriously flawed, containing examples of all the more common faults. After deciding to condemn this casting it was sectioned as mentioned above and examined as a check on the radiographic work.

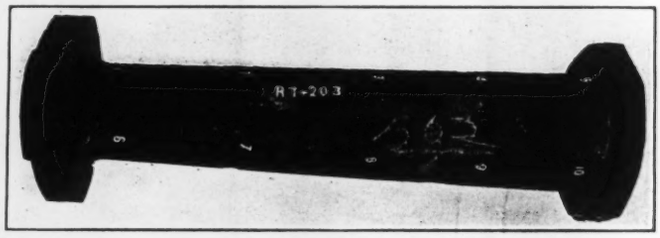

FIG. 11 NOZZLE EXTERIOR, SHOWING AREAS RADIOGRAPHED

Fig. 10 shows a general view of the nozzle as it is installed. It forms part of a bypass intended to transfer high-pressure steam at 1200 lb. to the normal-pressure system at 350 lb. The nozzle is made in three sections, the throat, the center, and the low-pressure section. It has a total length of approximately 11 ft. The internal diameter at the throat is approximately $1^3/_4$ in., and at the low-pressure end, $9^3/_4$ in. The casting under consideration is at the low-pressure end having a maximum internal diameter of $9^3/_4$ in.

For examination this casting was divided into twenty areas for radiographs. Four radiographs were taken near each flange, and twelve at various points along the nozzle body. These sections were arranged as shown in Fig. 11. Characteristic radiographs are shown in Figs. 12–15. They show the metal in the body of the casting. The small circular spots are caused by gas pockets of corresponding size in the metal. The actual size averages about $^1/_8$ in. in diameter. The fernlike pattern indicates the presence of shrinkage voids in the interior of the metal. This is not necessarily a serious weakness as it is caused by the sponginess of the metal between the sound faces. In this case there is a distinct tendency for the sponginess to become continuous, resulting in incipient cracks and a general porosity of the section which would probably tend to form leaks after a period of service. Figs. 14 and 15 show the appearance of the metal at the flanges. Here the condition

is quite serious; gas and shrinkage voids are indicated through the entire body of the material, and in addition the presence of sand inclusions is indicated by the cloudy shadows shown on the radiograph. In Fig. 15 a dark line at the fillet indicates the presence of a crack at the base of the flange at this point.

Following the X-ray examination the casting was cut into sections. Two cross-sections were taken from the body of the nozzle. Longitudinal sections were then made through the flanges and these sections were deeply etched so as to develop the structure of the metal and make the flaws easily visible. Fig. 16 shows the relation of the longitudinal sections and one of the cross-sections. It is at once evident that the metal is extremely porous due to shrinkage voids and has a large number of gas cavities. The most serious feature, however, is the fine shrinkage cracks reaching from the fillet back of the flange and the large cracks running from the interior of the nozzle up into the center of the flange where they meet a highly porous section. This condition is probably caused by improper mold structure. It is probable that the metal flowed out around the end of the core so that on cooling it was impossible for the pipe section to shrink properly along the core and the end was subjected to considerable tension which caused the cracks running up into the core center. Apparently, also, the body of the mold exerted too much pressure on the back faces of the flanges so that a tension stress was concentrated at the flange fillet, causing the fine cracks to form. These flaws certainly rendered the casting unfit for use and their detection may be considered as fully justifying the use of X-ray examination.

A study of the physical and chemical qualities of the material in this nozzle shows that it would have been of high quality had the molding work been successful. A number of specimens were cut from different parts of the nozzle and tested in a tension machine. In general the metal where sound showed satisfactory characteristics, but there was a very decided tendency toward undue brittleness. The appearance of the tension-test specimens is shown in Fig. 17. These specimens show that in the region of flawed material, while the strength is affected to some degree, the elongation and reduction of area are reduced very markedly indeed. Fig. 18 shows a characteristic photomicrograph of the material; the dark spots indicate microscopic cavities, and the general coarseness of the structure is indicated by the dendritic formation clearly shown at the side of the photomicrograph.

The study of this casting in connection with the radiographs gave a very positive check on their interpretation. It formed a basis for comparison with the results obtained from other castings so that the work could be interpreted with confidence.

A further example of the application of X-ray work is the governor-valve body for the high-pressure turbine. This valve body is a rather intricate casting comprising a double-beat valve and a steam-strainer shell in one casting. Fig. 19 gives the general idea of the appearance of the casting. Owing to the complicated internal structure required by the valve ports, the location of X-ray photographs was rather difficult and it was necessary to make a number of comparatively small radiographs in order to develop the quality of the material.

In general the casting was found to be satisfactory, but parts were rather gassy and there was a noticeable amount of dirt in the steel. Fig. 20 shows a characteristic radiograph of the poorer part of the casting.

The flaws shown were in general of rounded form and not of the irregular type which tend to form cracks. As the working stress in the metal is comparatively low it was decided to accept the casting, subject to hydrostatic test for leakage and extensometer test for elastic limit.

FIG. 12 RADIOGRAPH OF AREA 14, SLIGHTLY REDUCED

FIG. 13 RADIOGRAPH OF AREA 19, SLIGHTLY REDUCED

FIG. 14 RADIOGRAPH OF AREA 5, SLIGHTLY REDUCED

FIG. 15 RADIOGRAPH OF AREA 20, SLIGHTLY REDUCED

After machining, the casting was blanked off for hydrostatic-pressure test. Before applying the pressure, stops were welded to different parts of the casting for micrometer-gage application. The casting was then measured to give the initial micrometer readings and the water pressure applied. The micrometer readings were repeated under various pressure steps and found to increase very uniformly up to a pressure of 5000 lb., which was the maximum test pressure stipulated. No leaks developed and the pressure was then released, the micrometer readings being repeated. The casting returned very nearly to its original dimensions within a few seconds, but half a minute elapsed before the original dimensions were completely regained. This lag is considered as an indication that the

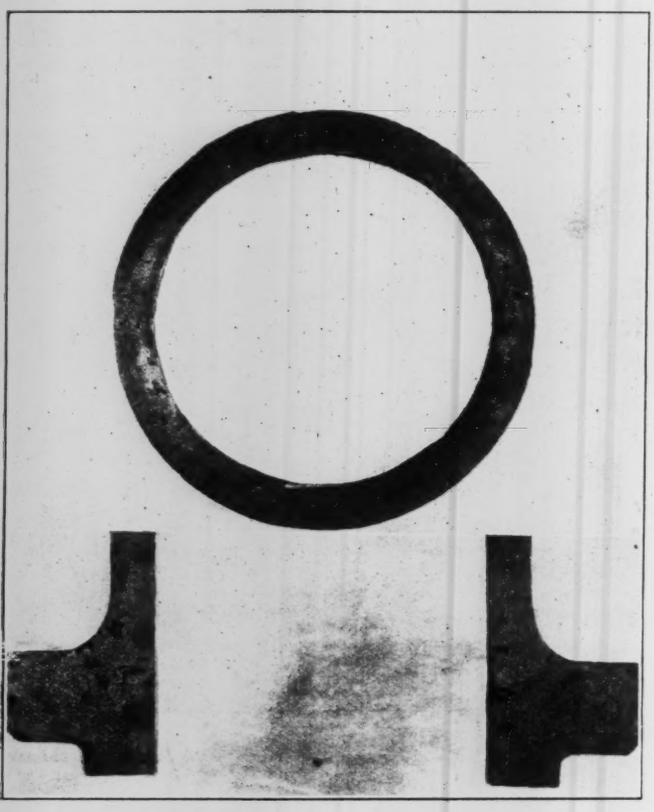

Fig. 16 Etched Sections (Photograph), Slightly Reduced

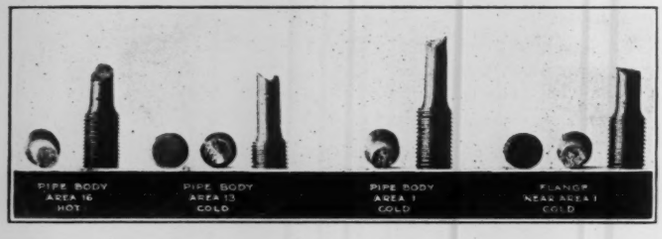

Fig. 17 Test Specimens

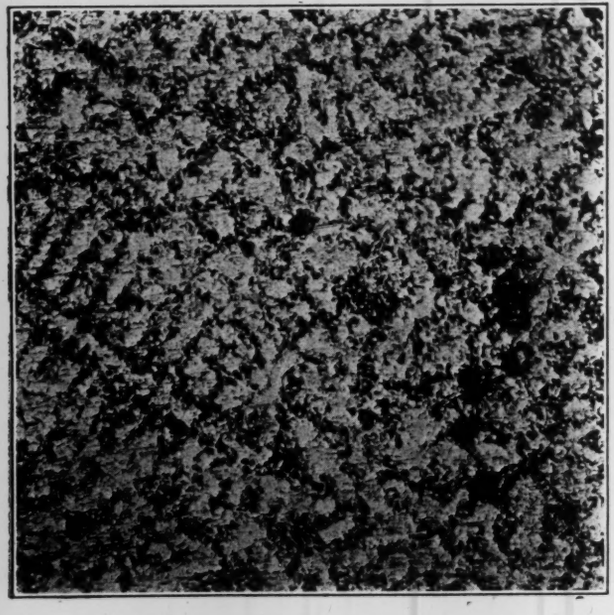

Fig. 18 Photomicrograph Showing Dendritic Structure (× 50)

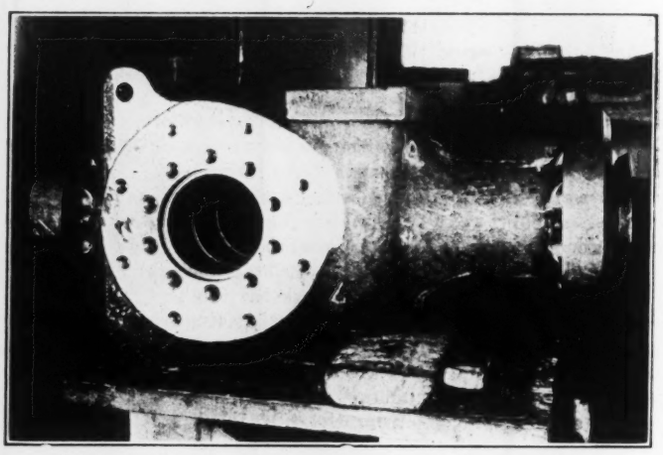

Fig 19 Valve Body

Fig. 20 Radiograph of Valve Body Shown in Fig. 19, Slightly Reduced

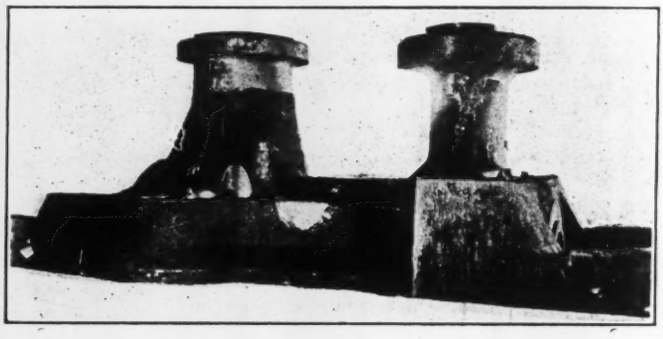

Fig. 21 Exterior of Bottom Half of Turbine Casing

Fig. 22 Radiograph of Inlet-Nozzle Flaws, Slightly Reduced

elastic limit of the material was closely approached, but inasmuch as the original dimensions were completely regained it is assumed that the elastic limit was not exceeded. These measurements under high pressures are considered very important as demonstrating approximately the elastic limit under service conditions. In this case they show positively that the operating pressure of 1200 lb. is protected by a factor of safety of more than four, based on the elastic limit. Taking this demonstration in conjunction with the X-ray studies which indicate that there are no flaws which would tend to be aggravated by operating conditions, the status of the casting is fully determined.

FIG. 23 RADIOGRAPH OF EXHAUST-NOZZLE FLAWS, SLIGHTLY REDUCED

The turbine casing, both top and bottom halves, was fully investigated except for certain sections which exceeded the thickness which can be penetrated by rays at the present time. Fortunately these very heavy sections are not subject to critical stresses and are therefore not a matter of serious concern. The top half of the casing was found to be an exceptionally fine piece of work. It is practically flawless. The bottom half of the casing (Fig. 21) is equally sound with the exception of the inlet and exhaust nozzles, which contain a certain amount of gassy metal associated with some dirt. (See. Figs. 22 and 23.)

The radiographs were carefully studied in conjunction with the working pressures and metal thicknesses of the various parts. No flaws were indicated which would tend to form cracks or leaks, or extend during service. The problem then resolved itself into a determination of the amount of weakening due to the flaws and the probable resultant factor of safety of the casting. In the high-pressure nozzle the working stresses are low and the flaws are so small that their effect is of no commercial importance. In the exhaust nozzle the flaws are in general of the same magnitude as those in the inlet nozzle, but a large gas pocket was discovered behind a heavy boss. This pocket was fully outlined by the X-ray photographs and its extent defined. It was found to have no serious effect on the strength of the casting owing to the thickness of metal at that point. It introduced a point of incipient leakage, however, which was very objectionable as the steam pressure on the exhaust of this turbine is some 360 lb. per sq. in. gage. To meet this condition a plan was worked out for drilling out and bushing the casting at the boss and welding the bushing into place. With this correction a hydrostatic-pressure test was applied in conjunction with extensometer measurements, and the strength of the casting was checked in about the same way as the governor-valve body.

This work is particularly interesting as demonstrating the ability of the X-rays to define the extent of flaws and save a casting which might otherwise have to be abandoned due to uncertainty as to its actual internal condition. It may be noted here that the turbine-casing halves are the heaviest castings ever examined by X-rays.

CONCLUSION

In all, some thirty castings were examined for the high-pressure steam installation at Weymouth. Out of these only five proved seriously defective; the remainder were for the most part of extremely high quality. Through the use of X-ray examinations it was possible to eliminate castings which would have been unequal to the service owing to flaws that were invisible from the surfaces, and to demonstrate with a reasonable degree of certainty the soundness and strength of the castings accepted. In this way the objectives laid out in the beginning of the examination were achieved and the cost of the work, if considered as an insurance charge, was fully justified.

The observations made form an excellent basis for a further study of the materials in this installation as affected by the conditions of service. The experience gained should be of value not only in the design of future installations but also in coöperating with the foundries in eliminating the flaws found to be characteristic of certain designs and methods of manufacture.

X-ray technique is now very effective, but its economic use is not yet fully developed. In presenting this paper it is hoped, therefore, that the work described may be of interest in solving similar power-station problems and may suggest a basis for future development.

Defects in Large Forgings

Some of the Common Defects Encountered and a Brief Explanation of Their Causes—Methods Used to Insure Uniform and Homogeneous Material

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THE object of this paper is not to imply that all large forgings are defective or in any way to condemn their use, but to point out to designing and operating engineers some of the places at which defects may be encountered.

It must always be borne in mind that the type of stress which exists in the part and the nature of the operating conditions determine in many cases the danger of a slight flaw or defect. In many cases the seriousness of flaws or defects cannot be accurately determined by laboratory means, and it is only after years of experience under actual operating conditions that one can disregard certain defects in certain types of equipment which must be the cause of rejection in other equipment.

The statement is often made that the materials of today are not as good as they were formerly. This is not true; they are infinitely better today, but the masses used, the speeds operated at, and the temperatures and pressures now found in modern apparatus were not even considered a few years ago. It is this new order of things which calls for greater uniformity and homogeneity of materials. Most engineering formulas are based on a uniform material, but steel makers and fabricators assert that no such material is possible, or made, in the strict meaning of the word, and the formulation of an estimate of the seriousness of any defect in a specific piece of apparatus therefore becomes a compromise between theory and practice.

In considering defects found in forgings, it is well to classify them under two heads: first, those inherent in the material; and second, those caused by the method of fabrication. It is very common to have both kinds present, and it is entirely possible that one may so mask or so accentuate the other as to make any definite conclusions difficult.

Material Defects

The most common defects inherent in the material or the ingot from which forgings are made, are:

1 Variations in composition
2 Piping and gas pockets
3 Cracks
4 Slag lines and "ghost lines."

Variations in Composition. In the manufacture of large forgings, large ingots, which in reality are only steel castings of the highest type, are required. Such castings will naturally have varying cooling rates, and it is a law of solutions—and steel is a solution—that the higher concentrations will solidify first. It is only natural, therefore, that the chemical composition will vary somewhat from the bottom to the top, and from the center to the outside, of the ingot.

This variation, if not excessive, is of no great importance. The slight variations in physical properties from one end to the other can usually be corrected by heat treatment of the forging; and it is the usual practice to test the forging midway between the center and the outside to get the average results.

However, any practice in which two heats of steel are utilized without the employment of a large mixing ladle, or in which two ladles of steel are poured without the use of a common runner box, should be frowned upon.

Piping and Gas Pockets. As stated before, an ingot is nothing more than a very special steel casting, and as such it is subject to many of the defects of steel castings.

The mold, in the best practice today, is made of special cast iron. The laws of freezing of metals cause the outside surface next to the mold to solidify first, and as more heat is absorbed by the mold this skin grows in thickness. This thickness grows more slowly as the metal solidifies, due to the increased mold temperature and the insulating effect of the skin, causing the center to remain molten for a considerable time.

This freezing action is accompanied by contraction which causes the molten metal in the center portion to decrease in height, giving the hollow, cone-shaped upper portion known as the "sink head" or "pipe." If the rate of solidification is not proper, the outer portions of the ingot, being rigid, will exert enormous stresses on this inner semi-solid material, causing tearing or extension of the pipe.

This tendency to tear is further increased due to the rejection of the impurities into the last material to solidify. This action is more fully explained under the discussion of "Cracks."

Ingots of proper design as to shape and cooling rates should have the pipe or shrink entirely confined to the upper portion. But if due to improper design, or if two heats or ladles of material are improperly used, or the pouring or cooling is stopped at any one point, the ingot can easily have piping throughout its length or in several places. The surfaces of these pipe cavities are usually oxidized, which prevents any possibility of welding in subsequent forging operations.

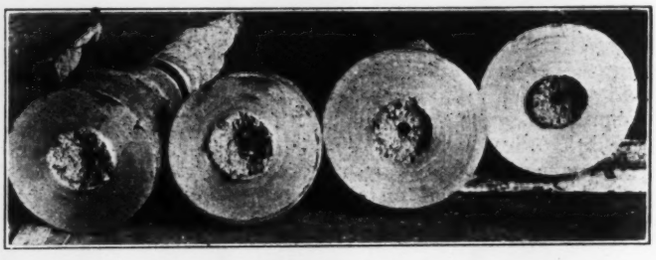

Fig. 1 Examples of Hidden Piping

The two forgings shown in Fig. 1, which have been cut in two, show examples of hidden pipe. In the case of both forgings the defects shown are due to secondary piping, for ample material had been cut from the top of the ingots to remove all normal shrinkage.

Gas pockets or blowholes are due to the rejection of gas by the molten steel at the time of solidification. If the solidification is normal, that is, progressing from the outside inward and from the bottom upward, the gas is carried into the sink head. But if the freezing takes place above molten metal and this gas collects, there will be a gas pocket which will cause trouble.

If considerable gas is present, a number of small bubbles will probably form just below the skin of the ingot and escape outward, leaving tiny "worm holes." The holes are usually oxidized and cause surface seams on forging or rolling. The extent of these seams are dependent on the depth of the gas "worm holes."

Cracks. If the surface of the ingot is not properly designed or the surface of the mold is rough or full of holes, natural contraction cannot take place and the ingot will crack.

Solidification begins about various centers which are at the lowest temperature, which results in the formation of crystal skeletons. These skeletons rapidly develop branches which become more and more coated with crystallizing matter until the whole resembles a tree or is, as it is termed, "dendritic."

In the case of an ingot the formation of a number of dendrites proceeds simultaneously from the chilled surface of the iron mold until they interlock and the whole material is solid. Impurities, having the lowest freezing temperature, will be carried in the mother liquid until final solidification, when they will be trapped between the dendritic branches.

If the dendritic formation proceeds from two surfaces it forces the non-metallics in the molten material to their extremities, until, when the dendrites interlock, a plane of inclusions is formed.

This plane of inclusions is a plane of weakness and can be the

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cause of a serious crack in an ingot and the forgings therefrom; and it is for this reason that the shape of the ingot mold, as regards surface, is designed so carefully, in order to obtain the maximum cooling surface with the minimum of corner segregation.

Slag Lines and Ghost Lines. "Ghost line" is a rather indefinite term applied to a frequently encountered defect. Ghost lines are streaks varying in composition from the major portion of the metal and usually containing slag impurities. They usually show up in the machined surface of the forging as light or dark

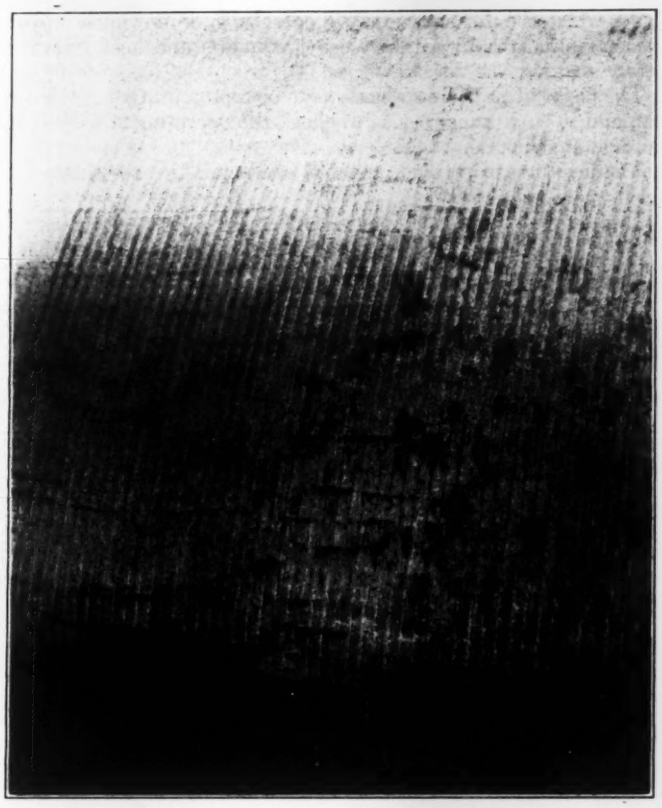

FIG. 2 GHOST LINES IN THE MACHINED SURFACE OF A SHAFT

marks, depending on the angle at which the light strikes the machined surface. As mentioned before, the material in these lines differs in composition from the rest of the steel, being usually very low in carbon and high in phosphorus. These lines differ in hardness from the surrounding material, which causes the tool to jump in machining and the lines to show. The depth of these marks is usually very small, so that with a very slight removal of material they disappear. However, when present they usually occur in many groups, and when one is removed, another appears.

The danger from these lines is a much-debated question. It can be safely said that in straight tension the strength of the material containing the lines differs little, if at all, from that of adjacent material containing no lines. However, the action under reversed stress is another matter, and that under temperature changes appears to the author to be detrimental. Being of radically different composition, the expansion and contraction are different from what they are in the surrounding material. It is because of these two unknown variables, reversed stresses and temperature variations, that ghost lines are prohibited in high-class equipment.

Fig. 2 shows the machined surface of a shaft illustrating a bad condition of ghost lines.

FABRICATION DEFECTS

Defects due to fabrication may be classified under the following heads: 1, Laps; 2, Star cracks; 3, Clinks; 4, Improper reduction; 5, Heat treatment.

Laps. Laps are the folding over of the surface of the metal in the forging operation. This type of defect is usually due to working the metal too much in one direction before rotating it, or to the use of improper forging dies. It can also occur with proper working and die equipment if the shape of the ingot surface—the corrugations—is not correctly designed.

In large forgings this type of defect is usually not serious, as the amount of stock left to be taken off the rough forging in the machining operation is usually sufficient to remove all traces of the lap. However, the surfaces of a lap are covered with a scale which is folded under, and the lap may be so severe as to cause actual tearing of the metal. It is purely a case of bad forging practice and should be looked upon with suspicion, as other poor practices often accompany it when it is allowed to exist.

Star Cracks. Star cracks, so called from their most familiar shape, are another form of bad forging practice. They are formed in the center of a shaft and are usually not seen unless the shaft is bored. The common cause of this type of failure is forging after insufficient heating, that is, working the hot outer portion over the cold center and causing it to fracture.

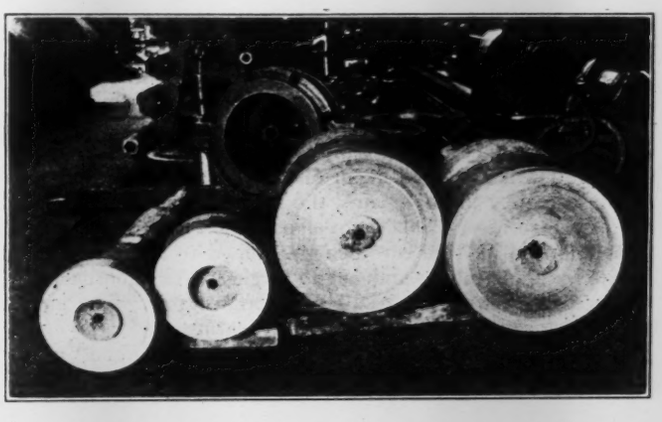

FIG. 3 SHAFTS SHOWING THE CLINK TYPE OF DEFECT

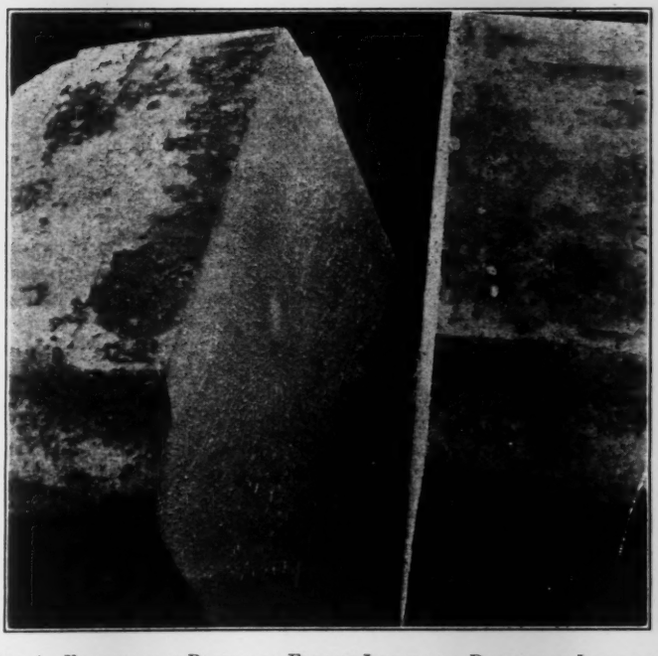

FIG. 4 FRACTURE OF PARTIALLY FORGED INGOT AS A RESULT OF INTERNAL STRESS

Forging a large section on too small a hammer or press, or forging it down round instead of square as far as possible and then rounding it up, can also produce these defects.

Clinks. Clinks are one of the greatest possible dangers in the making of large forgings, and while they are not necessarily produced by bad practice, they are the result of not exercising proper care.

In the casting of large ingots or even small ingots of alloy steels, enormous stresses are set up in the cooling. If this cooling is allowed to extend below about 1000 deg. fahr. without being equalized, these stresses usually reach such a point as to cause rupture.

It is therefore considered good practice not to allow a large ingot, or the forging from it, to cool completely until it has been heated uniformly to above the critical temperature of the material.

It is obvious that it is often impossible to get the cycles of operations to come so that they will allow the completion of the forging before cooling. It is often necessary to ship ingots to other plants for the forging operation, but in all such cases they should be annealed to relieve the casting strains.

On reheating an ingot, the rate of heating until the center portion has passed the temperature of 1000 deg. fahr. should be very slow, otherwise the expansion of the outer portion will cause a clink.

The reheating of a forging which is partially forged and the equalizing of the temperature of the finished forging are operations which demand the greatest of care and experience if this class of defect is to be eliminated. The occurrence of clinks increases with the size of the work and the use of the denser alloy steels.

Fig. 3 shows two shafts which have been cut in two and which exhibit the clink type of defect. A comparison between the defects in this illustration and those of Fig. 1 clearly shows the different characteristics of these two types of defects. The defects due to pipe have a coarse-grained, heavily oxidized surface, while the clinks exhibit a clean rupture of solid metal.

Fig. 4 shows a piece of partially forged ingot which has ruptured. This ingot, which was 23 in. in diameter, was heated and forged to approximately 21 in. square; the ingot corrugation can still be seen at the corners. This piece of material cooled down and was set to one side with no care being exercised to relieve the strains set up by the heating and slight forging. Six months later it fractured as shown as a result of internal stress. The material was perfect, containing no flaw of any nature.

Improper Reduction. The major object in forging a piece of steel is to break up the grain size found in a steel casting and to increase the density and homogeneity of the material.

To accomplish this the original area of the ingot must be reduced. In order to gain the maximum advantage this reduction should be in a direction at right angles to that in which the maximum stress will be applied in the finished article. Furthermore, the physical tests made to determine the characteristics should be taken at a position to determine this condition of maximum stress.

Reduction causes the dendritic crystallization and the secondary crystallization to be elongated at right angles to the applied force. This produces what is commonly termed "fiber," and greatly increases the physical properties in the parallel direction but at considerable sacrifice to the transverse ductility.

It is for this reason that ring forgings are forged by expanding over a mandrel and tested tangentially. While it is impossible to work some material, such as turbo rotor shafts which are stressed and tested radially, by expansion, the Allis-Chalmers Company has found that by proper heat treatment a fairly large reduction, with its accompanying advantages, can be made with no sacrifice in strength or ductility in any direction.

Because of the fibering of the structure of forgings, care should be exercised that a change of dimension in the forging operation is made by a flow and not by a sharp cut-off. If the flow of material is not obtained a weakness at the points of changes in diameter is experienced.

Heat Treatment. Defects due to the heat treatment of forgings is one subject which would demand many pages for its consideration, even in very rough outline. However, there are several major points of caution which can well be mentioned.

Any heat treatment should be applied only after all forging operations have been completed.

The heating and cooling should be uniform and applied to the entire mass, eliminating all possibilities of local heating or cooling of any part.

In large forgings the effect of mass must be considered, and time must be allowed for the complete penetration of the heat. It should be appreciated that there is a certain amount of inertia present which resists structural changes, and that the larger the mass, the greater will be the length of time necessary to accomplish any change.

Any heat treatment that obtains high physical strengths but leaves the material in a highly stressed condition, should be avoided.

A uniform distribution of the microscopic constituents in as fine a size as possible should be the desire, in order to prevent cleavage planes of weakness.

The Allis-Chalmers Company has found that to secure good large forgings the following precautions must be taken, not on one or two forgings but on each and every forging.

The ingots used for making the forgings must be made under careful supervision as to material melted, method of melting, temperatures obtained, pouring conditions, and mechanical handling.

The forging operations are closely controlled as to the heating and forging. The forge department is apprised of the stresses under which the finished piece will operate, in order that it may get the maximum results attainable by reduction and heat treatment before making the forging.

The physical tests are so made as to be representative of the forging, and in such a manner as to check the operating stresses in the finished machine.

The heat treatment and chemical characteristics are checked by careful microscopic examination and analysis before the forging is released by the metallurgical department.

FIG. 5 PERISCOPE USED FOR EXAMINING THE BORE OF A SHAFT

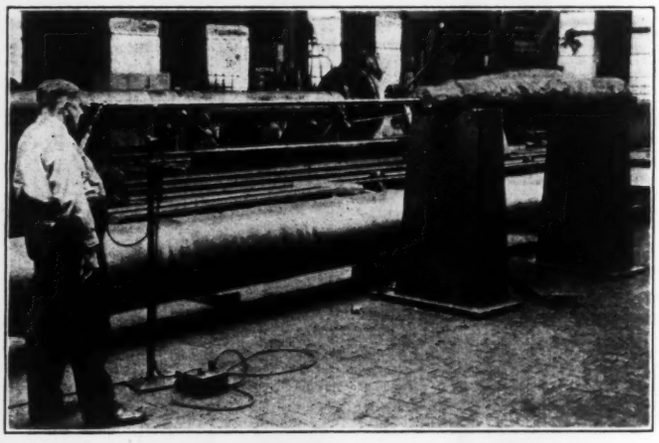

FIG. 6 PERISCOPE OF FIG. 5 IN USE

All laps, cracks, seams, or surface defects are completely chipped out before the piece is machined. Great care is used to see that all traces of the defect are removed, even to the extent of etching and examining with the microscope. In defects of this kind there is great danger that the metal at the base of the visual crack will be found to be distorted or microscopically ruptured, and if such material were allowed in service, there would be risk of fatigue failure.

All shafts over 9 in. in diameter have an exploratory hole (1½ in. in diameter or larger) for use in periscopic examination.

There are several types of periscopes for this work, but the one which has been used with success for the past ten years is shown in Figs. 5 and 6.

This instrument consists of a brass tube, the inner end of which contains an electric light for illuminating the bore, and a reflecting prism. The outer end has a focusing telescope, the object of which is to bring the image up to the eye, and not to magnify it. This equipment allows the slightest flaws to be detected within the bore of the shaft.

It is believed that with the careful observations as outlined above, large forgings today offer the best means of securing homogeneous material. However, a full understanding of the nature of defects and their reference to operating stresses should be thoroughly understood by all operating and designing engineers. It is this neglect to realize the limitations of large forgings which has caused them, through failures, to fall into disrepute; while in reality they are today one of our most uniform materials of construction.

Formulas for Computing the Economies of Labor-Saving Equipment

By JAMES A. SHEPARD,[1] MONTOUR FALLS, N. Y., AND GEORGE E. HAGEMANN,[2] NEW YORK, N. Y.

The engineer and manufacturer have heretofore been without correct and adequate means for measuring the relative economies of two or more industrial operations or installations of equipment. Proposed new apparatus might indicate a saving in manual labor, but this did not guarantee that it could be profitably substituted for machines or devices in use at the time. Such formulas as existed to determine this latter point were too complicated to be easily applied and generally used.

The present paper, following that of a year ago when the first engineering attack was made on the problem, develops five simple equations for determining the economies of an installation of labor-saving equipment. They show the maximum investment which will earn simple interest; the yearly cost to maintain the mechanical equipment ready for operation; the yearly profit, in excess of simple interest, from the operation of the equipment; the yearly profit from operation, in per cent on investment; and the years required for complete amortization of investment out of earnings. The method of applying these formulas, the evaluation of their various factors, and the correct assumption of bases, are explained in detail. The calculation of a labor-burden account, as distinct from the ordinary factory-burden account, and the transfer of certain items from the regular burden account to a special productive-labor-payroll account are recommended and explained. Standard forms to systematize investigations are worked out.

THE modern conception of engineering has broadened the engineer's field of activity to include responsibility for economic as well as technical achievements. It is essential, therefore, that dependable and convenient methods for economic research be furnished him; also that provision be made in our accounting systems for developing economic information to enable him to predict the results which will follow the adoption of his recommendations.

Periodic shortage of industrial labor, its rapidly increasing direct cost, and an indirect cost of considerable magnitude incidental to its employment under modern factory conditions, render accurate methods for analyzing its economic relation to mechanical aids and substitutes a matter of prime importance. Under the relatively simple organization of our industries a generation ago, comparative efficiency estimates, based upon the exercise of personal intuition or judgment, may have closely approximated reality. The relatively complex organizations which present-day conditions make essential usually render such crude processes of estimating inadequate and inaccurate.

A survey made for the purpose of finding out what current practice was followed in evaluating labor saved by improved organization or mechanical equipment, brought out the facts that:

1 There is in use no adequate or generally accepted method for estimating the comparative economic value of alternative industrial processes, or for evaluating labor saved.
2 Individual practice usually approximates one of two widely divergent methods. The one most frequently employed estimates the value of labor saved at its base or payroll rate, with no contingent addition. The other, more rarely used, but growing in favor because of the palpable inaccuracy of the first, estimates the value of labor saved at the payroll rate plus full factory burden. The range of variation in practice which has been observed between these two methods is as high as 500 per cent.

Common procedure having failed to produce any foundation for an adequate system of industrial economic analysis, it becomes necessary, in view of the obvious needs of the engineering profession and of industry, to build up a suitable system. As might be expected, there is not unanimity of opinion as to the requirements for such a system.

It is admitted that the basic principles involved have been identified previously, and that there are extant formulas which, when skillfully applied, are capable of solving the economic problems of both engineering and industry. Experience has proved, however, that it is impracticable for any except economic specialists to employ successfully the methods heretofore available. As a matter of fact, a generation, during which their necessity has been appreciated, has not brought them into practical use in industry to any great extent. While it is possible for the engineer to use them, it is improbable that he will in general do so.

Elements for Industrial Economic Research

The following elements are considered requisite in making up a system for industrial economic research adapted to the needs of the engineer:

1 Formulas adapted for integrating in a single equation the factors involved in usual industrial economic problems
2 Standardized values for all economic factors which are capable of standardization
3 Standardized methods for developing the values of economic factors which are variable
4 Standard forms to afford a uniform procedure in economic research, and to reduce the clerical work involved
5 Standard forms for summarizing economic data so as to constitute a uniform and thus comparable record.

The details of the system should show the entire process of analysis in a manner easily checked, corrected, or modified.

The System Recommended

The formulas reported to the Materials Handling Division by a Sub-Committee during the Spring Meeting at Montreal in 1923 possess advantages which led to their approval by the Committee for the following reasons:

1 They are so composed as to develop in five simple equations all facts usually required
2 Unlike other methods available, both debit and credit factors are utilized. Hence the formulas give results in terms of net performance
3 The factors employed generally represent a single element of value. They are composite only where, in current practice, familiar elements are combined and are closely related. Standardized values may therefore be readily and accurately applied
4 They combine flexibility with mathematical exactness in a degree not heretofore possible.

In their original form, in deference to established methods of cost accounting, the credit factor "T, yearly saving in fixed charges, operating charges or burden, in dollars," was made to cover indirect costs arising from the employment of both labor and mechanical equipment. It has been found desirable to separate this factor into two elements, as follows:

T_a = yearly saving in labor burden, in dollars
T_b = yearly fixed charges, in dollars, on mechanical equipment employed as a standard of comparison, or which will be displaced.

T_a therefore represents the difference in indirect cost of labor (labor burden) between the two processes which are under comparison.

T_b represents the aggregate value of $A + B + C + D$, expressed in dollars, applied to mechanical equipment which is being used as a standard of comparison or which will be displaced.

Formulas for Computing the Economies of Labor-Saving Equipment

The formulas for computing the economies of labor-saving equip-

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ment are presented for adoption in the following modified form:

Let:

Debit Factors:
- A = percentage allowance on investment
- B = percentage allowance to provide for insurance, taxes, etc.
- C = percentage allowance to provide for upkeep
- D = percentage allowance to provide for depreciation and obsolescence
- E = yearly cost of power, supplies, and other items which are consumed, total in dollars

Credit Factors:
- S = yearly saving in direct cost of labor, in dollars
- T_a = yearly saving in labor burden, in dollars
- T_b = yearly fixed charges, in dollars, on mechanical equipment employed as a standard of comparison or which will be displaced
- U = yearly saving or earning through increased production, in dollars
- X = percentage of year during which equipment will be operated
- I = initial cost of mechanical equipment
- K = unamortized value of equipment displaced, less its resale or scrap value

Results:
- Z = maximum investment, in dollars, which will earn simple interest
- Y = yearly cost to maintain mechanical equipment ready for operation (fixed charges)
- V = yearly profit, in excess of simple interest, from operation of mechanical equipment
- P = yearly profit from operation, in per cent on investment
- H = years required for complete amortization of investment out of earnings.

Then

$$Z = \left[\frac{(S + T_a + U - E)X + T_b}{A + B + C + D}\right] - K \quad [1]$$

$$Y = I(A + B + C + D) \quad [2]$$

$$V = [(S + T_a + U - E)X + T_b] - [Y + (KA)] \quad [3]$$

$$P = \frac{V}{I} + A \quad [4]$$

$$H = \frac{100 \text{ per cent}}{P + D} \quad [5]$$

VALUATION FOR DEBIT FACTORS OF THE FORMULAS

The debit factors A, B, C, D, and E employed in the formulas are capable of having arbitrary valuations assigned to them when related to definite classes of materials handling or other mechanical equipment. The Committee is now engaged in standardizing these values. When this work is completed the use of these standards will avoid the employment of improvised, and consequently erratic, values, and will tend to make analyses, conducted according to the proposed system, of standard composition and hence truly comparable.

VALUATION FOR CREDIT FACTORS OF THE FORMULAS

The credit factor "S, yearly saving in direct cost of labor, in dollars," must of course be developed by a detailed analysis of the processes under investigation. The hourly saving in labor, valued at the base or payroll rate, should be multiplied by 2400 working hours (300 eight-hour days) to develop the saving for a *full year*. This value, with other credit factors, becomes adjusted to the actual conditions when modified by the factor "X, percentage of the year during which the equipment will be operated."

The credit factor "T_a, yearly saving in labor burden, in dollars," as already explained, represents the difference in indirect cost of labor required by alternative processes. Details of the indirect expenditures which are elements of this factor are given later on in this paper.

The credit factor "T_b, yearly fixed charges, in dollars, on mechanical equipment employed as a standard of comparison, or which will be displaced," is the aggregate value $A + B + C + D$ expressed in dollars. The total of these factors appears in the formulas as a credit, opposed to the equivalent aggregate of the same factors applied to the alternative mechanical equipment as a debit, expressed in per cent.

ITEMS WHICH ARE ELEMENTS OF T_a AND T_b

In the employment of either labor or mechanical equipment under factory conditions there are two separate classes of expense, direct and indirect. Direct expenditures, as a rule, may be readily determined. Indirect expenses are more difficult to identify.

One manufacturer who has made a careful analysis of the indirect expenses incidental to the employment of factory labor for the year 1923, determines the average ratio of indirect expense to payroll, for his entire plant, at 58.6 per cent. Since the conditions in this factory were fairly representative of its class, it is evident that any system which evaluates labor, whether labor used or labor saved, at the base or payroll rate, with no addition for indirect expenses, results in substantial error.

In arriving at the cost of labor used it is now customary to add to the payroll rate, as overhead expense or burden, a percentage sufficient to cover all indirect expenses. In recognition of the error arising from a failure to make a suitable addition in the case of labor saved, some have adopted the practice of adding for labor saved an amount equal to that added for labor used. It is true that the cost of labor is substantially the same, whether it is labor used or saved. Hence if the overhead, or burden percentage, were composed exclusively of items which are incidental to the employment of labor, it would be, when added to the payroll rate, a true measure of the value of labor, whether used or saved.

Unfortunately for such a purpose, however, cost-accounting systems do not usually develop as burden an amount covering simply the indirect cost of labor, because of the equal necessity for prorating to product, in terms of percentage added to productive labor, the direct and indirect expenses of the factory equipment, as well as a variety of other expenses which can be thereby more accurately, or conveniently, distributed into the cost of product. As a consequence factory burden, as currently accounted, covers not only the indirect cost of labor but also taxes, insurance, depreciation, maintenance, and all other fixed charges against plant and equipment; the cost of power, heating, lighting, etc.; and the payroll pertaining to all labor classed as non-productive. Accordingly we have, by using present accounting methods for our purpose, two primary sources of error in the burden account when setting a value on labor saved:

1. The burden account is excessive as a measure of the indirect cost of labor, because it contains much that is irrelevant to labor costs
2. A portion of the productive labor has been classified as non-productive, and has been charged to the burden account instead of to the productive-payroll account; that is, the productive-labor account does not cover all of the labor which is truly productive.

As an expedient in accountancy it is entirely rational to classify as non-productive certain labor which is in fact productive. The work of yard men, truckmen, crane operators, and all others who handle materials cannot in some instances be charged directly to product. Hence such labor is properly classified as non-productive for accounting purposes, and is made a part of factory burden. It is irrational, however, to employ a factory burden thus composed as a measure of the incidental cost of labor. It is equally irrational merely because certain labor has been given a fictitious classification for accounting purposes, to give it a similar fictitious valuation in an efficiency study.

In a plant or department having a burden rate of 100 per cent a workman who receives 70 cents per hour cannot properly be said to cost $1.40 per hour when operating an engine lathe upon product, and but 70 cents per hour when repairing this engine lathe. Charging the labor at the varying rates may produce accurate final results in accounting the cost of product, but it fails completely as a means for developing the true cost of the labor performed, or saved.

From the foregoing explanation it becomes clear that to meet the needs of the engineer in arriving at a value for labor saved by a revision in processes, or by improved mechanical equipment, a new factor must be developed by the cost accountant which shall

include all items of expense incidental to the employment of labor, and which shall exclude all items of the factory burden which are irrelevant to the employment of labor. It is suggested that the new factor be differentiated in name, as in composition, by calling it "Labor Burden."

As a practical illustration of the relation which labor burden may be expected to bear to factory burden, a comparison is given here, developed by a manufacturer according to the methods above suggested, and based upon the conditions prevailing in his plant for the year 1923.

$$\text{Factory burden} = \frac{\text{Total of factory-burden account}}{\text{Total of regular productive payroll}} = \frac{\$417{,}036.70}{\$280{,}585.05} = 148 \text{ per cent}$$

$$\text{Labor burden} = \frac{\text{Total of labor-burden account}}{\text{Total of special productive payroll}} = \frac{\$170{,}757.71}{\$290{,}947.51} = 58.6 \text{ per cent}$$

$$\text{Relative ratio} = \frac{\text{Labor burden}}{\text{Factory burden}} = 39.6 \text{ per cent}$$

The figures given are an average for the entire plant, and were developed for the purpose of showing the wide difference between factory burden and labor burden. Current practice in developing separate burden values for each department of the factory, while equally applicable in the case of the labor burden, is not considered equally necessary.

Factory burden may vary widely. Variations exceeding 400 per cent between departments of a factory or in different industries are not unusual, owing to the wide differences in the relation which fixed charges (such as taxes, insurance, depreciation, maintenance, etc., upon buildings, machinery, and tools) bear to the productive-labor payroll. Fixed charges upon plant represent an important element of factory burden, hence relatively high factory-burden rates follow when the relation of investment in plant and equipment to productive payroll is high. They are relatively low when the relative investment in plant and equipment to productive payroll is low.

The items of indirect expense which go to make up labor burden, being independent of the physical surroundings under which the labor is performed, and arising purely out of the organization and related factors necessary for the direction and control of labor, may be expected to remain fairly uniform under a given type of organization. Such differences as are to be expected would arise principally through a varying relation between the relative elaborateness of organization conventional in a given line of business, and the relative wage scale. Experience seems to indicate, however, that the more highly skilled and hence highly paid trades generally demand a more elaborate and hence more costly organization for their guidance, and that accordingly the *percentage* which labor burden bears to payroll may not be subject to much variation in correctly organized industries of a given class.

The development of the exact labor burden pertaining to an industry, or to any department of an industry, is a simple matter in case extreme exactness is desirable. Labor burden may be developed from the same accounting which develops factory burden, values of the items which are chosen to compose the labor burden being carried to an extra column so as to form a separate total.

An important difference in the functions performed by factory burden and labor burden should not be overlooked in choosing items which are to be included in the latter. Factory burden represents an average ratio which a certain class or group of expenditures bears to productive labor in making up the cost of a given product or service. Hence a high degree of exactness in reflecting actual factory conditions *at the time the work is done* is essential as a means of developing actual factory costs at that particular period. Labor burden also represents an average ratio which a restricted class or group of expenditures, incidental to the employment of labor, bears to productive labor. Since those items of expense are already elements of factory burden, they have no further significance in the accounting system except as a guide for the future in estimating the prospective cost of similar elements of expense, under modified conditions. Accordingly a high degree of present exactness is not essential, whereas the closest possible approximation to average conditions which may be expected *through a series of years* is desirable.

The common expedient of rejecting in the accounting an item of economy because it cannot be realized immediately, is not applicable in making up labor burden. The broad principle that, in the long run, incidental expenses will rise and fall proportionately with the productive payroll, becomes applicable.

ITEMS RECOMMENDED FOR A LABOR-BURDEN ACCOUNT IN THE METAL TRADES

When making up a labor-burden account, variations will be necessary to meet the requirements of different kinds of industries. The one here presented is fitted to the needs of the metal trades. The Materials Handling Committee will compile lists for other trades as rapidly as possible.

Entire Cost, with the exception of percentage assessed to non-productive departments	Factory supervision Foremen and assistants Employment department Factory accounting departments Factory stenographers and clerks Safety department Stores office Tool storage Production department, including all subdivisions Traffic department Employees taking inventory Extra compensation for overtime, etc. (if accounted as an item of burden) Watchmen, gatemen, and ushers Instruction to apprentices Cleaners, oilers, and porters Cleaning and miscellaneous work by productive workmen All other similar expenditures.

Factory supervision should not be construed to cover supervision of the drafting room when it is a factory department. Foremen and assistants in non-productive departments such as tool room, pattern shop, development work and plant-improvement work, should be excluded from the special burden account.

Entire Cost	Accident compensation insurance Sick benefit and employees' relief Employees' death benefit Shop vacation allowances Maintenance of hospital, cafeteria, club, and welfare activities Gratuities Defective work and other losses due to errors Complaints and correction of product Factory office supplies Miscellaneous factory supplies All other similar expenses.
Part Cost	Building rental Factory insurance Fire department Factory taxes Maintenance of land and factory buildings Factory depreciation.

In assessing the percentage of insurance, fire department, taxes, maintenance, and depreciation, that percentage of the total cost should be included in the labor burden which will represent the *proportion of the occupancy of the building by workmen* as compared to other types of occupancy.

Since the regular productive payrolls do not ordinarily cover all of the labor which contributes toward production, the following classes of labor, often accounted as non-productive as far as they are included in the regular burden account, should be transferred from the regular burden account to the special productive labor payroll:

ITEMS RECOMMENDED TO BE TRANSFERRED FROM REGULAR BURDEN ACCOUNT TO SPECIAL PRODUCTIVE-LABOR PAYROLL

Entire Payroll	Railway crews Materials-handling and miscellaneous labor Stores department materials-handling labor Auto truckers and helpers Inspectors Receiving and disbursing raw stock Crane and elevator operators Shipping department All other similar labor.

The following classes of labor, as far as they are included in the regular productive payroll, should be deducted in order to develop the special productive labor payroll:

ITEMS RECOMMENDED TO BE DEDUCTED FROM REGULAR PRODUCTIVE PAYROLL TO DEVELOP THE SPECIAL PRODUCTIVE-LABOR PAYROLL

Entire Payroll	Drafting room Tool room Pattern shop All development work All plant improvement work.

The percentage which the labor-burden total bears to the corrected or special productive-labor-payroll total will represent the labor burden in the form of a percentage to be added to all productive labor. This process will develop a general labor-burden percentage. Where the burden accounting is departmentalized, a similar process conducted for each department will develop the departmental labor burdens.

A method which has been found convenient for developing labor burden consists in providing additional columns on the analysis sheet so that items may be transferred, as far as desired, from the regular burden account to these extra columns to form the labor-burden account. The values for both accountings are thus developed in parallel. A specimen form for such work is given in Table 1.

NECESSITY FOR A CORRECT ASSUMPTION OF BASES

Experience in the use of the formulas for computing the economies of labor-saving equipment indicates that a correct assumption of bases upon which an economic analysis is to be conducted is equally vital with the subsequent mathematical treatment. The following suggestions are offered as a guide to methods which have been found preferable.

1 The valuation for the factor I should cover the complete cost of mechanical equipment, including special tools, dies, jigs, or other special apparatus; also motive power, in case the motor or other driving agency is a part of or direct connected to the equipment; also cost of installation.

2 The proposed equipment (called No. 1 Equipment on the analysis form, Table 2) should be assumed to operate for as great a percentage of the standard year of 2400 hours (any other number of hours may be substituted) as conditions will justify.

The function of the factor X in the formulas is to separate time during which the equipment under analysis is in operation productively, and therefore profitably, from idle time during which it is under fixed expense but non-productive. Therefore X_1 should be assumed at the closest approximation to 100 per cent which will reflect actual conditions.

For instance, suppose that we are analyzing the comparative efficiency of a machine tool which is to operate upon an item of product not required in sufficient quantity to occupy the equipment full time for a standard year, but the machine is capable of operating upon other items of product also, at approximately equal efficiency. The problem may be solved most conveniently by arbitrarily considering the full range of jobs as one, and extending the operating time to a full year for the main work under analysis.

As an alternative which will eliminate all errors made in an approximation like the above, each of a group of operations, which will together occupy the machine for a full year, may be analyzed individually, with the value of X_1 developed for each separately. The analysis for each item of the product should then be conducted according to the formulas, except that the percentage representing the value of $(A + B + C + D)$ should first be multiplied by X_1, this product being employed in the equations. The total of all results will then represent the true efficiency for the year's operations.

TABLE 1 SEPARATION OF FACTORY BURDEN AND LABOR BURDEN

	Indirect Manufacturing Expenses	Factory-Burden Account: Non-productive payroll (Col. No. 1)	Factory-Burden Account: Other expense (Col. No. 2)	Factory-Burden Account: Total regular burden (Col. No. 3)	Labor-Burden Account: Total labor burden (Col. No. 4)	Labor-Burden Account: Transferred to productive payroll (Col. No. 5)
General						
1	Supervision, cost, employment, production, watchmen, cleaners, overtime, stores office, etc.	$ 69,552.24	744.39	70,296.63	59,752.13	
2	Supplies, misc. expense, etc.	25.33	10,307.64	10,332.97	8,783.02	
3	Accident compensation, hospital, sick and death benefit		13,665.25	13,665.25	11,615.46	
4	Purchasing, receiving, unassignable, freight, express and cartage	6,890.64	1,878.78	8,769.42		
5	Telegraph, telephone, traveling, etc.		8,040.87	8,040.87		
6	Insurance, taxes, depreciation		9,809.76	9,809.76	3,269.94	
7	Maintenance	1,586.58	1,353.29	2,939.87	2,498.88	
8	Miscellaneous labor	736.11		736.11		736.11
	Total	$ 78,790.90	$ 45,799.98	$124,590.88	$ 85,919.43	$ 736.11
Departmental Service						
1	Small tools, maintainance, and replacements to tools and jigs, etc.	13,608.61	18,100.87	31,709.48		
2	Auto truckers, helpers, stock room	12,440.89	3,109.95	15,550.85	3,109.95	12,440.89
3	Tool crib	7,284.26	72.51	7,356.77	7,356.77	
	Total	$ 33,333.76	$ 21,283.33	$ 54,617.09	$ 10,466.72	$12,440.89
Power Plant						
1	Operating labor	6,682.14		6,682.14		
2	Fuel and other supplies		15,730.11	15,730.11		
3	Maintenance	905.41	983.50	1,888.91		
4	Insurance, taxes, depreciation		3,886.10	3,886.10		
	Total	$ 7,587.55	$ 20,599.71	$ 28,187.26		
Direct Departmental Expense of Machine Shop, Assembly Shop, etc.						
1	Foremen, despatchers, cleaners, overtime	35,702.11	665.62	36,367.73	36,367.73	
2	Inspectors, laborers, stock, distribution, etc.	36,862.26	2,496.00	39,358.26	2,496.00	36,862.26
3	Defective work	745.45	18,595.19	19,340.64	19,340.64	
4	Defective purchased material and shop supplies		19,053.25	19,053.25		
5	Insurance, taxes, depreciation		39,556.33	39,556.33	13,458.58	
6	Maintenance, land and buildings, machinery, tools, patterns, etc.	17,647.86	6,084.77	23,732.63	2,708.61	
	Total	$ 90,957.68	$ 86,451.16	$177,408.84	$ 74,371.56	$36,862.26

Direct Departmental Expense of Drafting Room, Tool Room and Pattern Shop					
1 Supervision, foremen and other labor.	22,506.75		22,506.75		
2 Supplies		4,014.04	4,014.04		
3 Insurance, taxes, depreciation		4.552.54	4,552.54		
4 Maintenance	659.92	499.38	1,159.30		
Total	$ 23,166.67	$ 9,065.96	$ 32,232.63		
Total Manufacturing Expense	$233,836.56	$183,200.14	$417,036.70	$170,757.71	$50,039.26
	Footing No. 1	Footing No. 2	Footing No. 3	Footing No. 4	Footing No. 5

DEVELOPMENT OF FACTORY BURDEN

Total of all factory payrolls	$514,421.61
Less total of non-productive payroll, Footing No. 1	233,836.56
Difference = regular productive-labor payroll = Footing No. 6	$280,585.05

$$\text{Factory Burden} = \frac{\text{Total of Factory-Burden Account, Footing No. 3}}{\text{Total of Regular Productive Payroll, Footing No. 6}} = \frac{\$417{,}036.70}{\$280{,}585.05} = 148 \text{ per cent}$$

DEVELOPMENT OF LABOR BURDEN

Regular productive payroll, Footing No. 6	$280,585.05
Less drafting, tool, pattern and plant-improvement payrolls	39,676.80
	$240,909.25
Plus items transferred to productive-labor payroll, Footing No. 5	50,039.26
Total of special productive-labor payroll, Footing No. 7	$290,947.51

$$\text{Labor Burden} = \frac{\text{Total of Labor-Burden Account, Footing No. 4}}{\text{Total of Special Productive Payroll, Footing No. 7}} = \frac{\$170{,}757.71}{\$290{,}947.51} = 58.6 \text{ per cent}$$

Ratio Labor Burden to Factory Burden = 39.6 per cent

TABLE 2 COMPARATIVE ECONOMIC ANALYSIS NO. 3

Showing values for Z, V, P, and H as per formulas recommended by A.S.M.E. Committee.

It is assumed that the use of No. 2 equipment is generally accepted practice, while No. 1 is under examination for comparative economic efficiency. The factor K should be given zero value unless No. 2 is in use and would therefore be displaced by No. 1 with a corresponding capital loss.

No. 1 (designated by subscript numeral 1): 1 Semi-Automatic Turret Lathe. Cost $6100; operating 2280 hours per year; requires 1 operator; hp. required, 5; cost of power, 3 cents per kw-hr; reduced occupancy of buildings valued at $115.

Operated for Equal Production in Comparison with

No. 2 (designated by subscript numeral 2): 2 Engine Lathes. Cost, $4800; operating 4320 hours per year; requires 2 operators; hp. required, 6; cost of power, 3 cents per kw-hr. This equipment is not in use.

Average Values. None.

DATA REQUIRED FOR ANALYSIS

No. 1 One Turret Lathe		1 year = 2400 hours		No. 2 Two Engine Lathes	
One		Number of units employed		Two	
$*X_1$ = 95%		Per cent of year employed	(X)	$*X_2$ = 90%	
A_1 = 6%		Per cent on investment	(A)	A_2 = 6%	
B_1 = 3%		Per cent for insurance, etc.	(B)	B_2 = 3%	
C_1 = 5%		Per cent for upkeep	(C)	C_2 = 5%	
D_1 = 10%		Per cent for depreciation	(D)	D_2 = 7.5%	
Total = 24%				Total = 21.5%	
E_1X_1 =	$ 250.00	Cost of power, etc.	(E)	E_2X_2 =	$ 284.00
2280 hr. at 60 cents	$1368.00	Cost of labor	(S)	4320 hr. at 70 cents	$3024.00
80% of payroll	$1094.40	Cost of labor burden	(T_a)	80% of payroll	$2419.20
$I_1(A_1+B_1+C_1+D_1)$ =	$1464.00	Cost of fixed charges	(T_b)	$I_2(A_2+B_2+C_2+D_2)$ =	$1032.00
Total for 95% of yr.	$4176.40	Cost of operation		Total for 90% of yr.	$6759.20
	115.00	Value of increased production	(U)		none
	$6100.00	Cost of equipment	(I)		$4800.00
		Unamortized value of equipment less resale value	(K)		$1320.00

VALUATION OF FACTORS

$A_1 + B_1 + C_1 + D_1$		24 % =	$A + B + C + D$
$E_1 - E_2$ =	$ 250.00 — $ 284.00 =	— $ 34.00 =	E
$S_2 - S_1$ =	$3024.00 — $1368.00 =	$1656.00 =	S
$T_{a2} - T_{a1}$ =	$2419.20 — $1094.40 =	$1324.80 =	T_a
T_{b2}	=	$1032.00 =	T_b
$U_1 - U_2$ =	$ 115.00 — none =	$ 115.00 =	U
[2] $Y_1 = I_1(A_1 + B_1 + C_1 + D_1)$	=	$1464.00 =	Y
I_1	=	$6100.00 =	I
K_2	=	$1320.00 =	K

* X is applied individually in Cases Nos. 1 and 2, hence 100 % = X

SOLUTIONS

Z = Maximum Investment Which Will Return Simple Interest on Investment

[1] $$Z = \left[\frac{(S + T_a + U - E)X + T_b}{A + B + C + D}\right] - K = \$17340.00$$

V = Yearly Profit from Operation

[3] $$V = [(S + T_a + U - E)X + T_b] - [Y + (KA)] = \$2697.80$$

If it is not found possible to make the group of operations cover a full standard year, then a correct result will be obtained by taking the factor $I_1(A + B + C + D)$, multiplying it by the percentage of a standard year during which the equipment is idle, and deducting the product from the above-named aggregate efficiency.

The factor X_2 should represent the percentage of a standard year during which the equipment to be displaced (No. 2 Equipment in Table 2) would produce an output equal to the proposed new equipment (No. 1 Equipment in Table 2), not, however, exceeding 100 per cent unless operated during a day-and-night run. For day-and-night running the maximum will be 200 per cent, beyond which two or more No. 2 (displaced) Equipments must be assumed. If not operated during a night run, for percentages above 100 it will be necessary to assume two or more No. 2 (displaced) Equipments.

For day-and-night operation it is usual to make the valuation for the factors C and D 150 per cent of that employed for a day run only.

3 The credit factor "U, yearly saving or earning through increased production, in dollars," in the sense contemplated by the formulas is the valuation, actual or potential, where an increase in production is or will be required and the usual expedient of extending the plant and employing more workmen is thereby avoided.

As an illustration: Two alternative processes show about equal efficiency on the usual comparative basis of equal production. One equipment, however, will be occupied 90 per cent of the time for required production. The other produces the necessary volume of product operating only 60 per cent of the time. Even though not needed at once, the potential extra productive capacity of the second equipment to meet unexpected demand has a certain money value as an insurance of ample product. If the extra productivity can be utilized, and an extra equipment and operator, with incidental building floor space, heating, lighting, etc. are thereby made unnecessary, a very much higher money value for increased production becomes appropriate.

In those cases where a strictly limited amount of product is required, and there are no accessory conditions which serve to give a potential or actual value to increased production, it may be necessary to give U a zero value.

P = Yearly Profit in Per Cent on Investment

$$P = \frac{V}{I} + A = \textbf{50.2 per cent} \quad [4]$$

H = Years for Complete Amortization of Investment Out of Profits

$$H = \frac{100\%}{P + D} = \textbf{1.66 years} \quad [5]$$

TABLE 3 SUMMARY OF ANALYSIS

Estimated actual investment required for No. 1		$6100.00
Estimated excess investment in No. 1 over No. 2, $I_1 - I_2$, or I_1		$1300.00
Estimated yearly profit from operation No. 1 over No. 2, excess above simple interest		$2697.80
Estimated value of reduced labor turnover		
Total		$2697.80
Estimated yearly profit from operation of No. 1 over No. 2 in per cent on investment, total		50.2 %
Estimated yearly profit from operation of No. 1 over No. 2 in per cent on excess investment, $\frac{I_1}{I_1 - I_2} P$, total		235%
Estimated time required to amortize entire cost of No. 1 out of earnings in excess of No. 2		1.66 years
Estimated time required to amortize excess cost of No. 1 over No. 2 out of earnings in excess of No. 2, $\frac{H}{\frac{I_1}{I_1 - I_2}}$		0.33 year

STANDARD FORM TO AFFORD UNIFORM PROCEDURE IN CONDUCTING ECONOMIC RESEARCHES

As a convenience to the engineer in conducting economic researches, to afford a readily readable record of the assumptions and processes employed, to standardize the work and results so that they will be comparable with similar researches, to guide the research along correct lines, avoiding oversight or error, and to save time, the form for comparative economic analyses shown in Table 2 is submitted.

STANDARD FORM FOR SUMMARIZING ECONOMIC DATA

The summary of an economic research shown in Table 3 reviews the factors which have an economic value, such as:

1 Estimated capital required
2 Estimated yearly profit over alternative
3 Estimated profit in per cent on investment
4 Estimated time required to amortize investment
5 Estimated saving through reduction in labor turnover.

It should also include practical considerations which may have no immediate money value, but which may nevertheless provide the ultimate weight of evidence for or against a given choice, such as:

6 Estimated relative flexibility to adapt to unforeseen conditions or types of product
7 Estimated relative continuity of service through relative durability, inherent reliability, or because of labor conditions.

The formulas and analyses above presented furnish the engineer with a ready and accurate device by which he can measure the economies of present and proposed operating methods and equipment, and decide correctly and with certainty between alternative proposals.

An Application of the Formulas for Computing Economies of Labor-Saving Equipment

BY GEORGE LANGFORD, JR.,[1] CHICAGO, ILL.

In this paper the A.S.M.E. Materials Handling Division's formulas for computing the economies of labor-saving equipment are applied to the purchase and operation of an electric industrial truck in place of hand lift trucks. The type of work done by the electric truck is described, and this description is followed by an analysis of the saving its adoption effected and a detailed explanation of the practical features involved in the evaluation of the various factors used by the formulas, together with a statement of the conclusions arrived at and of features beyond the scope of the formulas.

AT THE Spring Meeting of the A.S.M.E. held at Montreal, Canada, May 28 to 31, 1923, and in MECHANICAL ENGINEERING for September, 1923, the Materials Handling Division of the Society submitted a group of formulas for computing the economies of labor-saving equipment. A number of formulas accomplishing the same results were then in existence, but were so cumbersome and required so much knowledge of the subject of economics that they were utterly unfitted for the practical use of the average engineer.

The formulas evolved by the Materials Handling Division are designedly of extremely simple form and are very easily applied where there is a difference in labor by a new method as compared with an older method, whether it be some method or process, a material-handling device, or a machine tool.

Hypothetical analyses using these formulas have been published several times before, but while these are both interesting and instructive, an analysis of a practical application of these formulas may perhaps be of more positive value.

In December, 1924, the Belden Manufacturing Company of Chicago, Illinois, bought a type R-1 Wright-Hibbard elevating platform truck for use in their wire-drawing plant and magnet-wire plant. This truck (Fig. 1) was bought to take the place of several hand lift-truck operations and augment several others, and has been in continuous operation for the past three months. This electric industrial truck has a rated capacity of 2000 lb. with a weight of 1395 lb., which makes it especially convenient in plants having elevators of small capacity. It has a loaded speed of 4½ miles per hour and an empty speed of 6 miles per hour, both being a great deal faster than a workman will walk. For motive power it uses a 2-hp. 12-volt d.c. motor operating from either an Edison or lead battery of surprisingly small size. The charging equipment consists merely of a small-sized Hettner motor-generator set with a rheostat and voltmeter and ammeter, and generally has the battery on charge the better part of the night.

The truck is set to a great variety of uses. In the first place, it carries all of the copper rod used in the rod mill from the stock room in loads of from 1600 to 1800 lb. over a rough plank floor, and then over approximately 150 yd. of winding concrete aisles. It carries all of the coils of intermediate sizes of wire from the intermediate wire-drawing machines to the fine wire-drawing machines on lift trucks loaded with about 2000 lb. of copper wire—a run of 25 yd. over concrete. It carries all of the stranded wire used in the magnet-wire plant from the stranding department, which means a carry of about 175 yd. over concrete to the elevator, and then up on the elevator to the third floor. These loads will run up as high as 1500 lb. It carries a great deal of the finished magnet wire from the third floor to the second-floor stock room in loads of 1000 lb. or so. It carries large loads of empty spool trays much faster than can be done by hand lift trucks. It carries also large loads of packed cases of wire on spools from the various departments to the shipping department in loads up to 2000 lb. In short, it does all that was done with hand labor and the lift trucks, and more besides, the hand lift trucks being used almost exclusively now for short hauls and intradepartmental work.

It is not intended to explain the theory of the formulas or of their components, the Committee already having done that, but

[1] Belden Manufacturing Company.

Contributed by the Materials Handling Division for presentation at the Spring Meeting, Milwaukee, Wis., May 18 to 21, 1925, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. All papers are subject to revision.

Be sure to bring this copy with you to the Spring Meeting

it would be well to look into the practical resolution of the various components comprising the detailed analysis.

The cost of the truck was taken as the sum of its net cost, amounting to $1724.80; the net cost of the charging equipment, $348.97; the freight on these two items, $23.78; and the labor and supplies necessary for installation, $45.00; the total being $2142.55.

In the formulas the working year is taken as 300 days of 8 hr. each, but in all the departments of the Belden Manufacturing Company in which the truck is in operation, the working day is longer than that, which, when idle time is also taken into account, brings the working year up to approximately 2500 hr. The number of working hours in a year has really no effect on the operation of these formulas as they are relative to each other, power being reckoned for the year as a whole, and the various factors, such as

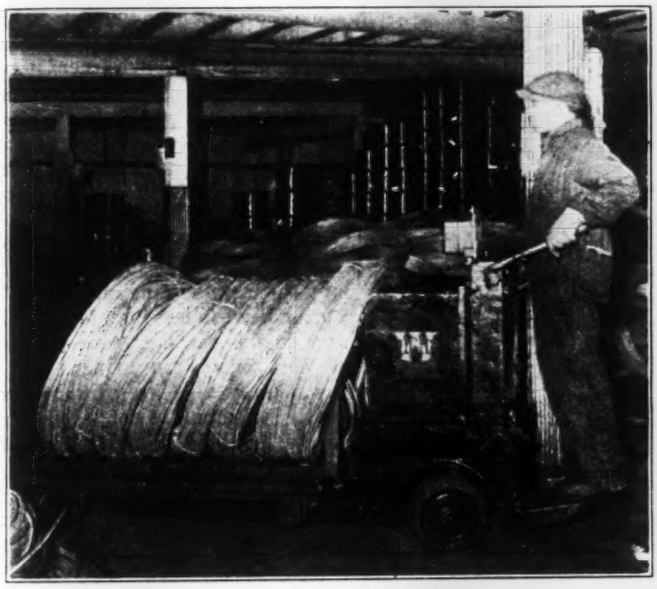

FIG. 1 ELECTRIC TRUCK HANDLING SKID OF 8 ROLLS OF PICKLED COPPER ROD WEIGHING ABOUT 215 LB. EACH

allowance on the investment, insurance, etc. being percentages on the total cost.

Six per cent was taken as the allowance on the investment, that being standard practice, and in like manner 4 per cent was assumed sufficient to cover the cost of insurance, etc.

In estimating the percentage of the working year that the units are in operation, the fact that the no-load time of the electric truck is less than the no-load time of the hand lift trucks accounts for the difference between 90 per cent and 80 per cent.

In figuring the percentage upkeep, care was taken to have all of the items higher than will probably be the actual case, for as the truck grows older the maintenance will undoubtedly be higher, and by setting a high average figure the results will be well on the safe side. Thirty dollars is ample to cover the cost of oil and grease per year, a Ford car using less than twice that amount. Fifteen dollars should provide plenty of distilled water and all of the acid that may slop out. A new set of tires costs approximately $30 and it is assumed that they will last a year in their present service. The daily repairs amount chiefly to testing the battery and adding water, and allowing half an hour per day for that at 55 cents, will amount to $84 per year. General repairs should be generously provided for by 10 per cent of total cost allowance, or $214.25. According to the manufacturers of the Exide battery the average life of one of their batteries in industrial-truck service is three years, and so the battery depreciation will amount to one-third of the installed cost of $175, or $58.33 per year. The sum total of these upkeep charges amounts to $431.58, or very close to 20 per cent on the total investment.

In figuring the depreciation charges as 17 per cent on the investment, the life of the truck was assumed to be six years. It is possible that it will last longer than that, but six years is on the safe side and carries the weight of authority.

The battery requires approximately 12 kw-hr. of current per night, current costing 1.4 cents per kw-hr., and as the small Hettner motor-generator set has a total efficiency of around 75 per cent, the power bill will run up to $67.20 per year.

The Wright-Hibbard truck requires but one operator, who does all of the driving of the truck and all of his own loading and unloading except in very isolated instances, in which cases other operators may lend him a hand in a spare moment. According to the best information obtainable, the truck takes the place of the labor of between 2.5 and 3.0 men, so again to be on the safe side, 2.5 is taken as the number of men the truck replaces. These hand-lift-truck men were paid 48 cents per hour, which for all of them amounts to $3330 per year. The electric-truck operator is paid 50 cents per hour, and his yearly pay amounts to $1387.50. In addition there is the labor of the night electrician, who spends approximately half an hour per night putting the truck on charge and seeing that it is charging properly, and this amounts to $82.50 per year, which brings the truck labor up to $1470 per year.

No accurate figures were available for use in calculating the labor burden, but good authority at the plant puts it at approximately 75 per cent of the payroll. In the case of hand labor this will amount to $2497.50 per year, and for the electric truck it will be $1105.50.

In the formulas the total fixed charges include the maintenance costs, so that the total fixed charges on the truck investment amount to 47 per cent on the total cost, or $1007 per year. The fixed charges on the hand labor will of course be nothing, no capital being involved.

It may be well to digress a trifle and explain that the hand lift trucks are really not actually displaced by the electric truck. It had been planned for some time previous to the actual purchase of the truck to acquire possession of one, the problem being to select a type from the many different makes on the market. With that end in view, when new hand lift trucks become necessary they were not purchased, with the result that the electric truck merely takes the place of some imaginary hand lift trucks and augments the ones actually in use. Thus it cannot properly be said that this replacement of imaginary equipment will have cost the company money, and so the unamortized value of the replaced equipment less resale value becomes zero. Inasmuch as the hand lift trucks are in use in both the cases under consideration, their debits and credits will cancel each other and not enter into the comparison at all, and so are left out of the calculations entirely.

The total cost of operation in the case of the electric truck will be the sum of the labor cost of $1470, the labor burden of $1105.50, the power cost of $67.20, and the total fixed charges of $1007, or $3649.70 per year. The total cost of operation in the case of the hand labor is the labor at $3330 and the labor burden at $2497.50, or $5827.50 per year.

It would be next to impossible to figure the value of the increased production of one method over the other, but the electric truck does reduce the labor turnover by 60 per cent, which is admittedly to the electric truck's credit. What this would amount to is probably not worth the time required to figure it out. The value of increased production is set at zero in each case.

The evaluation of the various factors in the analysis is simple and exactly as shown in the detailed analysis.

In solving for the maximum investment which will return simple interest on the investment, the electric truck has credit factors of $1860 for labor, $1392 for labor burden, nothing for either the fixed charges on the hand labor or the value of the increased production of the electric truck over hand labor, and a debit factor of $67.20 for the increased cost of power of the electric truck over hand labor. These factors are algebraically added, divided by the total of the fixed charges for the electric truck, or 47 per cent, and then the unamortized value of the hand equipment, which in this case amounts to zero, is subtracted. The maximum investment which will return simple interest on the investment, or the maximum allowable investment, will then be $6776.17, or approximately three times what was actually paid for the truck.

In figuring the yearly profit from the operation of the electric truck, the same credit and debit figures as before are totaled, and then have subtracted from them the total cost of the fixed charges on the truck and 6 per cent on the unamortized value of the replaced hand-lift-truck equipment; this yearly profit resulting from the

COMPARATIVE ECONOMIC ANALYSIS NO. 3

Showing values for Z, V, P, and H as per formulas recommended by A.S.M.E. Committee.

It is assumed that the use of No. 2 equipment is generally accepted practice, while No. 1 is under examination for comparative economic efficiency. The factor K should be given a zero value unless No. 2 is in use, and would therefore be displaced by No. 1 with a corresponding capital loss.

No. 1 (designated by subscript numeral 1): Wright-Hibbard Electric Industrial Truck. Cost, $2142.55; operating 2500 hours per year; requires 1 operator; hp. required, 2; cost of power, 1.4 cents per kw-hr.

Operated for Equal Production in Comparison with

No. 2 (designated by subscript numeral 2): Hand Labor. Cost, none; operating 2500 hours per year; requires 2.5 operators; hp. required, none; cost of power, none; This equipment recently in use. Average Values. None.

DATA REQUIRED FOR ANALYSIS

No. 1				No. 2	
		1 year = 2400 hours			
One		Number of units employed		2.5	
$*X_1 = 90\%$		Per cent of year employed	(X)	$*X_2 = 80\%$	
$A_1 = 6\%$		Per cent on investment	(A)	$A_2 = 0\%$	
$B_1 = 4\%$		Per cent for insurance, etc.	(B)	$B_2 = 0\%$	
$C_1 = 20\%$		Per cent for upkeep	(C)	$C_2 = 0\%$	
$D_1 = 17\%$		Per cent for depreciation	(D)	$D_2 = 0\%$	
Total = 47%				Total = 0%	
E_1X_1 =	$ 67.20	Cost of power, etc.	(E)	E_2X_2 =	$ 0.00
... hr. at...	$1470.00	Cost of labor	(S)	... hr. at...	$3330.00
75% of payroll	$1105.50	Cost of labor burden	(T_a)	75% of payroll	$2497.50
$I_1(A_1+B_1+C_1+D_1)$ =	$1007.00	Cost of fixed charges	(T_b)	$I_2(A_2+B_2+C_2+D_2)$ =	$ 0.00
Total for 104% of yr.	$3649.70	Cost of operation		Total for 104% of yr.	$5827.50
	0.00	Value of increased production	(U)		0.00
	$2142.55	Cost of equipment	(I)		$ 0.00
		Unamortized value of equipment less resale value	(K)		$ 0.00

VALUATION OF FACTORS

$A_1 + B_1 + C_1 + D_1$	= 47 %	=	$A + B + C + D$
$E_1 - E_2$	$ 67.20 — $ 0.00	= $ 67.20	= E
$S_2 - S_1$	$3330.00 — $1470.00	= $1860.00	= S
$T_{a2} - T_{a1}$	$2497.50 — $1105.50	= $1392.00	= T_a
T_{b2}		= $ 0.00	= T_b
$U_1 - U_2$	$ 0.00 — $ 0.00	= $ 0.00	= U
[2] $Y_1 = I_1(A_1 + B_1 + C_1 + D_1)$		= $1007.00	= Y
I_1		= $2142.55	= I
K_2		= $ 0.00	= K

*X is applied individually in Cases Nos. 1 and 2, hence 100 % = X

SOLUTIONS

Z = Maximum Investment Which Will Return Simple Interest on Investment

[1] $$Z = \left[\frac{(S + T_a + U - E)X + T_b}{A + B + C + D}\right] - K = \$6776.17$$

V = Yearly Profit from Operation

[3] $$V = [(S + T_a + U - E)X + T_b] - [Y + (KA)] = \$2177.80$$

P = Yearly Profit in Per Cent on Investment

[4] $$P = \frac{V}{I_1} + A_1 = 107.6 \text{ per cent}$$

H = Years for Complete Amortization of Investment out of Profits

[5] $$H = \frac{100\%}{P + D_1} = 0.803 \text{ year}$$

operation of the electric truck over the hand lift trucks amounting to $2177.80 per year, or more than the total cost of one truck.

The yearly profit in percentage on the investment is figured by dividing the yearly profit from the operation of the truck by the initial investment in the equipment, and adding to this the investment charges in per cent. This will then amount to 107.6 per cent yearly. The investment charge of 6 per cent is added to the per cent profit because in the debit factors evaluated in the previous equations the 6 per cent on the investment was deducted. In order to get the total or true percentage of profit it is necessary to add this 6 per cent. As the 6 per cent was subtracted in the one case and added in the other, the resultant will be zero, and the true percentage profit will really be the profit in dollars divided by the original investment.

To find the number of years for the complete amortization of the investment out of profits, 100 per cent is divided by the yearly profit on the investment in per cent plus the percentage depreciation on the investment, and amounts to 0.803 year, or a little less than ten months. That is, the machine will completely pay for itself out of profits in less than ten months of operation.

The results obtained from the use of these formulas are most interesting, and especially the fact that the electric truck will pay for itself in less than ten months and after that is earning more than its original cost every ten months. The formulas do not take into consideration the relative flexibilities of these two methods of handling materials, but inasmuch as the small electric truck will go practically wherever a hand lift truck can be pulled, and in addition will carry more than twice as much as a man can handle on a hand lift truck, the electric truck may rightfully be said to be the more flexible in operation of the two. In addition, the electric truck is efficient and well adapted for use on long, heavy hauls, where a hand lift truck would be almost impossible to use. The maximum speed of the loaded truck is about 4.5 miles per hour, which is a great deal faster than any man could be induced to pull a loaded hand lift truck.

This truck to date had been eminently satisfactory, barring one or two minor difficulties which have since been corrected, and while it is to be regretted that it has not been in operation long enough to provide a more accurate set of results and eliminate more of the estimations used, it is believed that the formulas fulfill extremely well the functions for which they were designed, and are of very great value in showing the relative value of the electric truck over the hand labor it replaces.

SUMMARY OF ANALYSIS NO. 3

Estimated actual investment required for No. 1	$2142.55
Estimated excess investment in No. 1 over No. 2, $I_1 - I_2$, or I_1	$2142.55
Estimated yearly profit from operation No. 1 over No. 2, excess above simple interest	$2177.80
Estimated value of reduced labor turnover	
Total	$2177.80
Estimated yearly profit from operation of No. 1 over No. 2 in per cent on investment, total	107.6%
Estimated yearly profit from operation of No. 1 over No. 2 in per cent on excess investment $\frac{I_1}{I_1 - I_2} P$, total	107.6%
Estimated time required to amortize entire cost of No. 1 out of earnings in excess of No. 2	0.803 year
Estimated time required to amortize excess cost of No. 1 over No. 2 out of earnings in excess of No. 2, $\frac{H}{\frac{I_1}{I_1 - I_2}}$	0.803 year

Remarks Covering Relative Flexibility, Safety, Durability, also Recommendation:

1 The electric truck is the more flexible of the two.
2 The electric truck is possibly the safer of the two as regards operation.
3 The electric truck is less durable than the hand lift trucks.
4 It is recommended that the electric truck be used.

Economic Efficiency of the Full-Automatic Turret Lathe in Comparison with the Semi-Turret Lathe

By R. J. WADD,[1] MONTOUR FALLS, N. Y.

This paper deals with the economic results arising from changes in machine-tool equipment as affected by the labor employed and the efficiency of production. Specific comparisons are instituted which are based on the work done by the full-automatic turret lathe and the semi-automatic turret lathe as analyzed with the aid of the recommended formulas developed by the Formulas Committee of the A.S.M.E. Materials Handling Division.

IN CONNECTION with the work that has been done by the Formulas Committee of the A.S.M.E. Materials Handling Division in developing formulas for computing the economies of labor-saving equipment, it may be of interest to examine the results of the comparison as applied by the recommended formulas to possible changes in machine-tool equipment.

Several years ago (1919), in bringing out a line of lighter-capacity hoists than it had ever manufactured, the company with which the author is associated was faced with the problem of increased production and shop costs lower than had been found possible in any article that it had previously produced. Anticipated sales requirements called for the running of larger-sized lots through the shop, which opened up the possibilities of changes in machine-tool equipment to obtain the increased production and decreased shop cost.

One of the economic changes made was from the semi-automatic turret lathe, employing one power-fed cutting position per operation, to the full-automatic type turret lathe with one or more power-driven cutting positions per operation on parts that would allow tooling for the cutting of more than one tool per operation; the former requiring an individual operator per machine, while with the latter it would be possible to group two or more machines around one operator. Before the required number of automatics and their tool equipment could be installed it was necessary to produce some of the parts on semi-automatic turret lathes. These lathes were practically new machines and all calculations are based on their originial investment charge. As the parts were swung over to the automatic turrets for production, actual costs of identical parts on the two types of machines became available. In the analyses under consideration the parts operated on were given the best possible conditions of manufacture on the two types of machines as regarded feeds, speeds, and tool equipment, and were equally applicable to the different machines under different conditions of quantity production.

Machining Winding Drums of Hoists. The winding drum of a one-ton hoist offered a comparative analysis of a full-automatic turret lathe and a semi-automatic turret lathe tooled to give practically equal production capacity. The drum required a finish over all on the barrel and on the flange at either end, and the hubs at either end were bored, counterbored, faced, and reamed. Two chucking operations were necessary per piece on either machine. The greater part of machining time was consumed in the finish of the barrel, which gave the semi-automatic turret lathe a slight advantage on production over the full-automatic turret on account of the heavier feeds and higher speeds allowable on the former machine. The full-automatic was required to operate continuously for the necessary production with from one to three cutting tools in position per operation, using one machine operator for two units, the second machine working on a

COMPARATIVE ECONOMIC ANALYSIS NO. 7

Showing values for Z, V, P, and H as per formulas recommended by A.S.M.E. Committee.

It is assumed that the use of equipment No. 2 is generally accepted practice, while No. 1 is under examination for comparative economic efficiency. The factor K should be given zero value unless No. 2 is in use and would therefore be displaced by No. 1 with a corresponding capital loss.

No. 1 (designated by subscript numeral 1): Full-Automatic Turret Lathe. Cost, $3450; operating 2400 hours per year; requires 1/2 operator's time; hp. required, 5; cost of power, 5 cents per kw-hr; one operator for two machines.

Operated for Equal Production in Comparison with

No. 2 (designated by subscript numeral 2): Semi-Automatic Turret Lathe. Cost, $3800; operating 2200 hours per year; requires 1 operator; hp. required, 4; cost of power, 5 cents per kw-hr. This equipment is not in use on this class of work, but was not discarded as plant equipment.

Average Values. Comparison based on lot of 3000 Class I hoist winding drums.

DATA REQUIRED FOR ANALYSIS

No. 1 Full Automatic		1 year = 2400 hours		No. 2 Semi-Automatic	
One		Number of units employed		One	
$*X_1$ = 100%		Per cent of year employed	(X)	$*X_2$ = 92 %	
A_1 = 6%		Per cent on investment	(A)	A_2 = 5.5%	
B_1 = 1%		Per cent for insurance, etc.	(B)	B_2 = 0.9%	
C_1 = 5%		Per cent for upkeep	(C)	C_2 = 4.6%	
D_1 = 10%		Per cent for depreciation	(D)	D_2 = 9.2%	
Total = 22%				Total = 20.2%	
E_1X_1 =	$ 450.00	Cost of power, etc.	(E)	E_2X_2 =	$ 330.00
2400 hr. at 40 cents	$ 960.00	Cost of labor	(S)	2200 hr. at 75 cents	$1650.00
59% of payroll	$ 566.40	Cost of labor burden	(T_a)	59% of payroll	$ 973.50
$I_1(A_1+B_1+C_1+D_1)$ =	$ 759.00	Cost of fixed charges	(T_b)	$I_2(A_2+B_2+C_2+D_2)$ =	$ 767.60
Total for 100% of yr.	$2735.40	Cost of operation		Total for 92% of yr.	$3721.10
	$ 0.00	Value of increased production	(U)		$ 0.00
	$3450.00	Cost of equipment	(I)		$3800.00
		Unamortized value of equipment less resale value	(K)		$ 0.00

VALUATION OF FACTORS

$A_1 + B_1 + C_1 + D_1$	=	22 %	= $A + B + C + D$
$E_1 - E_2$	$ 450.00 — $ 330.00 =	$ 120.00	= E
$S_2 - S_1$	$1650.00 — $ 960.00 =	$ 690.00	= S
$T_{a2} - T_{a1}$	$ 973.50 — $ 566.40 =	$ 407.10	= T_a
T_{b2}	=	$ 767.60	= T_b
$U_1 - U_2$	$ 0.00 — $ 0.00 =	$ 0.00	= U
[2] $Y_1 = I_1(A_1 + B_1 + C_1 + D_1)$	=	$ 759.00	= Y
I_1	=	$3450.00	= I
K_2	=	$ 0.00	= K

* X is applied individually in Cases Nos. 1 and 2, hence 100 % = X

SOLUTIONS

Z = Maximum Investment Which Will Return Simple Interest on Investment

[1] $$Z = \left[\frac{(S + T_a + U - E)X + T_b}{A + B + C + D}\right] - K = \$7930.45$$

V = Yearly Profit from Operation

[3] $$V = [(S + T_a + U - E)X + T_b] - [Y + (KA)] = \$985.70$$

P = Yearly Profit in Per Cent on Investment

[4] $$P = \frac{V}{I} + A = 34.5 \text{ per cent}$$

H = Years for Complete Amortization of Investment out of Profits

[5] $$H = \frac{100\%}{P + D} = 2.24 \text{ years}$$

[1] Ch. Engr., Shepard Elec. Crane & Hoist Co. Mem. A.S.M.E.

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Be sure to bring this copy with you to the Spring Meeting

COMPARATIVE ECONOMIC ANALYSIS NO. 8

Showing values for Z, V, P, and H as per formulas recommended by A.S.M.E. Committee.

It is assumed that the use of equipment No. 2 is generally accepted practice, while No. 1 is under examination for comparative economic efficiency. The factor K should be given zero value unless No. 2 is in use and would therefore be displaced by No. 1 with a corresponding capital loss.

No. 1 (designated by subscript numeral 1): Full-Automatic Turret Lathe. Cost, $3350; operating 2400 hours per year; requires 1/2 operator's time; hp. required, 4; cost of power, 5 cents per kw-hr.

Operated for Equal Production in Comparison with

No. 2 (designated by subscript numeral 2): Semi-Automatic Turret Lathe. Cost, $2800; operating 3250 hours per year; requires 1 operator; hp. required, 3; cost of power, 5 cents per kw-hr. This equipment is not in use on this class of work but was not discarded as plant equipment.

Average Values. Comparison based on lot of 6500 class A hoist gear gages.

Data Required for Analysis

No. 1 Full-Automatic		1 year = 2400 hours		No. 2 Semi-Automatic	
One		Number of units employed		One	
$*X_1$ = 100%		Per cent of year employed	(X)	$*X_2$ = 135.4%	
A_1 = 6%		Per cent on investment	(A)	A_2 = 6 %	
B_1 = 1%		Per cent for insurance, etc.	(B)	B_2 = 1 %	
C_1 = 5%		Per cent for upkeep	(C)	C_2 = 6.8%	
D_1 = 10%		Per cent for depreciation	(D)	D_2 = 11.8%	
Total = 22%				Total = 25.6%	
E_1X_1 =	$ 360.00	Cost of power, etc.	(E)	E_2X_2 =	$ 366.00
2400 hr. at 40 cents =	$ 960.00	Cost of labor	(S)	3250 hr. at 75 cents =	$2437.50
59% of payroll =	$ 566.40	Cost of labor burden	(T_a)	59% of payroll =	$1438.13
$I_1(A_1+B_1+C_1+D_1)$ =	$ 737.00	Cost of fixed charges	(T_b)	$I_2(A_2+B_2+C_2+D_2)$ =	$ 716.80
Total for 100% of yr.	$2623.40	Cost of operation		Total for 100% of yr.	$4958.43
	$ 0.00	Value of increased production	(U)		$ 0.00
	$3350.00	Cost of equipment	(I)		$2800.00
Unamortized value of equipment less resale value			(K)		$ 0.00

Valuation of Factors

$A_1 + B_1 + C_1 + D_1$	=	22 % = $A + B + C + D$
$E_1 - E_2$	$ 360.00 — $ 366.00 =	— $ 6.00 = E
$S_2 - S_1$	$2437.50 — $ 960.00 =	$1477.50 = S
$T_{a2} - T_{a1}$	$1438.13 — $ 566.40 =	$ 871.73 = T_a
T_{b2}	=	$ 716.80 = T_b
$U_1 - U_2$	$ 0.00 — 0.00 =	$ 0.00 = U
[2] $Y_1 = I_1(A_1 + B_1 + C_1 + D_1)$	=	$ 737.00 = Y
I_1	=	$3350.00 = I
K_2	=	0.00 = K

* X is applied individually in Cases Nos. 1 and 2, hence 100 % = X

Solutions

Z = Maximum Investment Which Will Return Simple Interest on Investment

[1] $$Z = \left[\frac{(S + T_a + U - E)X + T_b}{A + B + C + D}\right] - K = \$13{,}963.63$$

V = Yearly Profit from Operation

[3] $$V = [(S + T_a + U - E)X + T_b] - [(Y + (KA)] = \$2335.03$$

P = Yearly Profit in Per Cent on Investment

[4] $$P = \frac{V}{I} + A = 75.7 \text{ per cent}$$

H = Years for Complete Amortization of Investment out of Profits

[5] $$H = \frac{100\%}{P + D} = 1.16 \text{ years}$$

COMPARATIVE ECONOMIC ANALYSIS NO. 9

Showing values for Z, V, P, and H as per formulas recommended by A.S.M.E. Committee.

It is assumed that the use of equipment No. 2 is generally accepted practice, while No. 1 is under examination for comparative economic efficiency. The factor K should be given zero value unless No. 2 is in use and would therefore be displaced by No. 1 with a corresponding capital loss.

No. 1 (designated by subscript numeral 1): Full-Automatic Turret Lathe. Cost, $3350; operating 2400 hours per year; requires 1/2 operator's time; hp. required, 4; cost of power, 5 cents per kw-hr.

Operated for Equal Production in Comparison with

No. 2 (designated by subscript numeral 2): Semi-Automatic Turret Lathe. Cost $2800; operating 3250 hours per year; requires 1 operator; hp. required, 3; cost of power 5 cents per kw-hr. This equipment is not in use on this class of work, but was not discarded as plant equipment.

Average Values. Comparison based on lot of 6500 class A hoist gear gages.

Data Required for Analysis

No. 1 Full-Automatic		1 year = 2400 hours		No. 2 Semi-Automatic	
One		Number of units employed		Two	
$*X_1$ = 100%		Per cent of year employed	(X)	$*X_2$ = 67.7%	
A_1 = 6%		Per cent on investment	(A)	A_2 = 4.06%	
B_1 = 1%		Per cent for insurance, etc.	(B)	B_2 = 0.68%	
C_1 = 5%		Per cent for upkeep	(C)	C_2 = 3.39%	
D_1 = 10%		Per cent for depreciation	(D)	D_2 = 6.77%	
Total = 22%				Total = 14.90%	
E_1X_1 =	$ 360.00	Cost of power, etc.	(E)	E_2X_2 =	$ 366.00
2400 hr. at 40 cents =	$ 960.00	Cost of labor	(S)	3250 hr. at 75 cents	$2437.50
59% of payroll =	$ 566.40	Cost of labor burden	(T_a)	59% of payroll	$1438.13
$I_1(A_1+B_1+C_1+D_1)$ =	$ 737.00	Cost of fixed charges	(T_b)	$I_2(A_2+B_2+C_2+D_2)$ =	$ 834.40
Total for 100% of yr.	$2623.40	Cost of operation		Total for 67.7% of yr.	$5076.03
	$ 0.00	Value of increased production	(U)		$ 0.00
	$3350.00	Cost of equipment	(I)		$5600.00
Unamortized value of equipment less resale value			(K)		$ 0.00

Valuation of Factors

$A_1 + B_1 + C_1 + D_1$	=	22 % = $A + B + C + D$
$E_1 - E_2$	$ 360.00 — $ 366.00 =	— $ 6.00 = E
$S_2 - S_1$	$2437.50 — $ 960.00 =	$1477.50 = S
$T_{a2} - T_{a1}$	$1438.13 — $ 566.40 =	$ 871.73 = T_a
T_{b2}	=	$ 834.40 = T_b
$U_1 - U_2$	$ 0.00 — $ 0.00 =	$ 0.00 = U
[2] $Y_1 = I_1(A_1 + B_1 + C_1 + D_1)$	=	$ 737.00 = Y
I_1	=	$3350.00 = I
K_2	=	$ 0.00 = K

* X is applied individually in Cases Nos. 1 and 2, hence 100 % = X

Solutions

Z = Maximum Investment Which Will Return Simple Interest on Investment

[1] $$Z = \left[\frac{(S + T_a + U - E)X + T_b}{A + B + C + D}\right] - K = \$14{,}498.30$$

V = Yearly Profit from Operation

[3] $$V = [(S + T_a + U - E)X + T_b] - [Y + (KA)] = \$2452.63$$

P = Yearly Profit in Per Cent, on Investment

[4] $$P = \frac{V}{I} + A = 79.2 \text{ per cent}$$

H = Years for Complete Amortization of Investment out of Profits

[5] $$H = \frac{100\%}{P + D} = 1.12 \text{ years}$$

different part. The semi-automatic with one cutting tool per operation finished the production in 92 per cent of the time necessary for the full-automatic, but required an individual operator. The outstanding difference in operation was practically only in the amount of labor time involved. Analysis No. 7 gives the results obtained in this case.

Machining Hoist Gear Cages. Another possible analysis of the same-size full-automatic turret lathe and a semi-automatic turret lathe was in operation on a hoist gear cage, an ideal piece for efficient production on the former machine, in which case the time required on the full-automatic was considerably less than on the semi-automatic. The piece required turning at three different diameters three facing operations, an inside turn, and one boring and reaming operation. The semi-automatic lathe with its individual operator required 135 per cent of the time necessary on the full-automatic lathe, with one-half of the operator's time for attention. As it would have been possible to obtain the production on the semi-automatic lathe by running it overtime or by using two machines running approximately 67 per cent of the working year, analyses Nos. 8 and 9 are given to show whatever effect may result from variation in fixed charges.

Machining Hoist Gear Heads. An analysis of the same-size full automatic turret lathe and a semi-automatic vertical turret lathe was possible in a lot of hoist gear heads. The piece required two different turning operations, four facing operations, two different-diameter bores, and a bevel seat turned in one side of the piece. One full-automatic turret lathe worked continuously with one-half of the operator's time for production, while three semi-automatic vertical turret lathes with individual operators were required to run 83.3 per cent of the working year for equivalent production. Analysis No. 10 deals with the above operation.

All of the foregoing analyses demon-

COMPARATIVE ECONOMIC ANALYSIS NO. 10

Showing values for Z, V, P, and H as per formulas recommended by A.S.M.E. Committee.

It is assumed that the use of equipment No. 2 is generally accepted practice, while No. 1 is under examination for comparative economic efficiency. The factor K should be given zero value unless No. 2 is in use and would therefore be displaced by No. 1 with a corresponding capital loss.

No. 1 (designated by subscript numeral 1): Full-Automatic Turret Lathe. Cost, $3700; operating 2400 hours per year; requires 1/2 operator's time; hp. required, 5; cost of power, 5 cents per kw-hr.

Operated for Equal Production in Comparison with

No. 2 (designated by subscript numeral 2): Semi-Automatic Vertical Turret Lathe. Cost, $4200; operating 6000 hours per year; requires 1 operator; hp. required, 3; cost of power, 5 cents per kw-hr. This equipment is not in use on this class of work, but was not discarded as plant equipment.

Average Values. Comparison based on lot of 4500 class A hoist gear heads.

DATA REQUIRED FOR ANALYSIS

No. 1 Full-Automatic		1 year = 2400 hours		No. 2 Semi-Automatic	
One		Number of units employed		Three	
$*X_1$ = 100%		Per cent of year employed	(X)	$*X_2$ = 83.33%	
A_1 = 6%		Per cent on investment	(A)	A_2 = 5.00%	
B_1 = 1%		Per cent for insurance, etc.	(B)	B_2 = 0.83%	
C_1 = 5%		Per cent for upkeep	(C)	C_2 = 4.16%	
D_1 = 10%		Per cent for depreciation	(D)	D_2 = 8.33%	
Total = 22%				Total = 18.32%	
E_1X_1 =	$ 450.00	Cost of power, etc.	(E)	E_2X_2 =	$ 675.00
2400 hr. at 40 cents =	$ 960.00	Cost of labor	(S)	6000 hr. at 75 cents =	$4500.00
59% of payroll =	$ 566.40	Cost of labor burden	(T_a)	59% of payroll =	$2655.00
$I_1(A_1+B_1+C_1+D_1)$ =	$ 814.00	Cost of fixed charges	(T_b)	$I_2(A_2+B_2+C_2+D_2)$ =	$2308.30
Total for 100% of yr.	$2790.00	Cost of operation		Total for 83.3% of yr.	$10,138.30
	$ 0.00	Value of increased production	(U)		$ 0.00
	$3700.00	Cost of equipment	(I)		$12,600.00
		Unamortized value of equipment less resale value	(K)		$ 0.00

VALUATION OF FACTORS

	$A_1 + B_1 + C_1 + D_1$	=	22 % = $A + B + C + D$
	$E_1 - E_2$	$ 450.00 — $ 675.00 =	— $ 225.00 = E
	$S_2 - S_1$	$4500.00 — $ 960.00 =	$3540.00 = S
	$T_{a2} - T_{a1}$	$2655.00 — $ 566.40 =	$2088.60 = T_a
	T_{b2}	=	$2308.30 = T_b
	$U_1 - U_2$	$ 0.00 — $ 0.00 =	$ 0.00 = U
[2]	$Y_1 = I_1(A_1 + B_1 + C_1 + D_1)$	=	$ 814.00 = Y
	I_1	=	$3700.00 = I
	K_2	=	$ 0.00 = K
	* X is applied individually in Cases Nos. 1 and 2, hence		100 % = X

SOLUTIONS

Z = Maximum Investment Which Will Return Simple Interest on Investment

[1] $$Z = \left[\frac{(S + T_a + U - E)X + T_b}{A + B + C + D}\right] - K = \$37{,}099.54$$

V = Yearly Profit from Operation

[3] $$V = [(S + T_a + U - E] - [Y + (KA)] = \$7347.90$$

P = Yearly Profit in Per Cent on Investment

[4] $$P = \frac{V}{I} + A = 204.6 \text{ per cent}$$

H = Years for Complete Amortization of Investment out of Profits

[5] $$H = \frac{100\%}{P + D} = 0.46 \text{ year}$$

SUMMARY OF ANALYSIS NO. 7

Estimated actual investment required for No. 1	$3450.00
Estimated excess investment in No. 1 over No. 2, $I_1 - I_2$, or I_1.	−$ 350.00
Estimated yearly profit from operation No. 1 over No. 2, excess above simple interest	$ 985.70
Estimated value of reduced labor turnover	$ 0.00
Total	$ 985.70
Estimated yearly profit from operation of No. 1 over No. 2 in per cent on investment, total	34.5%
Estimated yearly profit from operation of No. 1 over No. 2 in per cent on excess investment, $\frac{I_1}{I_1 - I_2} P$, total	0.0%
Estimated time required to amortize entire cost of No. 1 out of earnings in excess of No. 2	2.24 years
Estimated time required to amortize excess cost of No. 1 over No. 2 out of earnings in excess of No. 2 $\frac{H}{\frac{I_2}{I_1 - I_2}}$	0.0 years

Remarks Covering Relative Flexibility, Safety, Durability, also Recommendation:

The saving shown above, as might be anticipated from the preceding statement, was practically entirely due to the decrease in the labor charge as shown by the comparison of items S_1, T_{a1} with S_2 and T_{a2}. Obviously the use of a considerably more expensive and less efficient machine would still have been justifiable had it been necessary.

SUMMARY OF ANALYSIS NO. 8

Estimated actual investment required for No. 1	$3350.00
Estimated excess investment in No. 1 over No. 2, $I_1 - I_2$, or I_1.	$ 550.00
Estimated yearly profit from operation No. 1 over No. 2, excess above simple interest	$2335.03
Estimated value of reduced labor turnover	0.00
Total	$2335.03
Estimated yearly profit from operation of No. 1 over No. 2 in per cent on investment, total	75.7%
Estimated yearly profit from operation of No. 1 over No. 2 in per cent on excess investment, $\frac{I_1}{I_1 - I_2} P$, total	454.2%
Estimated time required to amortize entire cost of No. 1 out of earnings in excess of No. 2	1.16 years
Estimated time required to amortize excess cost of No. 1 over No. 2 out of earning in excess of No. 2 $\frac{H}{\frac{I_1}{I_1 - I_2}}$	0.193 year

Remarks Covering Relative Flexibility, Safety, Durability, also Recommendation:

SUMMARY OF ANALYSIS NO. 9

Estimated actual investment required for No. 1	$3350.00
Estimated excess investment in No. 1 over No. 2, $I_1 - I_2$, or I_1.	−$2250.00

Estimated yearly profit from operation No. 1 over No. 2, excess above simple interest	$2452.63
Estimated value of reduced labor turnover	$ 0.00
Total	$2452.63
Estimated yearly profit from operation of No. 1 over No. 2 in per cent on investment, total	79.2%
Estimated yearly profit from operation of No. 1 over No. 2 in per cent on excess investment, $\frac{I_1}{I_1 - I_2} P$, total	0.0%
Estimated time required to amortize entire cost of No. 1 out of earnings in excess of No. 2	1.12 years
Estimated time required to amortize excess cost of No. 1 over No. 2 out of earnings in excess of No. 2, $\frac{H}{\frac{I_1}{I_1 - I_2}}$	0.0 year

Remarks Covering Relative Flexibility, Safety, Durability, also Recommendation:

Comparing the results of either Analysis No. 8 or No. 9 with those of Analysis No. 7 shows the increase in savings possible by the reduction in labor charge when the full-automatic was working on a part on which it could show an increase of production over the semi-automatic machine.

SUMMARY OF ANALYSIS NO. 10

Estimated actual investment required for No. 1	$3700.00
Estimated excess investment in No. 1 over No. 2, $I_1 - I_2$, or I_1	−$8900.00
Estimated yearly profit from operation No. 1 over No. 2, excess above simple interest	$7347.90
Estimated value of reduced labor turnover	$ 0.00
Total	$7347.90
Estimated yearly profit from operation of No. 1 over No. 2 in per cent on investment, total	204.6%
Estimated yearly profit from operation of No. 1 over No. 2 in per cent on excess investment, $\frac{I_1}{I_1 - I_2} P$, total	0.0%
Estimated time required to amortize entire cost of No. 1 out of earnings in excess of No. 2	0.46 year
Estimated time required to amortize excess cost of No. 1 over No. 2 out of earnings in excess of No. 2, $\frac{H}{\frac{I_1}{I_1 - I_2}}$	0.00 year

Remarks Covering Relative Flexibility, Safety, Durability, also Recommendation:

The above analysis exemplifies to a more marked degree the results obtained in Analyses Nos. 8 and 9.

strate very forcibly the economic possibilities of the full-automatic turret lathe on quantity production in which the set-up time for the machine becomes a negligible quantity as distributed over the output.

Labor-Saving Equipment in Road Construction

Description and Economic Analysis of a New Paver, Employing the A.S.M.E. Materials Handling Division's Formulas for Computing the Economies of Labor-Saving Equipment

BY E. H. LICHTENBERG,[1] MILWAUKEE, WIS., AND JAMES A. SHEPARD,[2] MONTOUR FALLS, N. Y.

This paper describes the economic results obtained by the use of improved equipment for mechanically handling concrete in road construction, which deposits the concrete so nearly into its final position as to require very little manual labor aside from that involved in finishing the surface.

The paper is accompanied by an economic analysis comparing the performance of the improved type of handling equipment with an earlier and less efficient type, in which the Formulas for Computing the Economies of Labor-Saving Equipment are applied.

IT IS ESTIMATED that during the year 1923 there were in the United States between 1000 and 2000 road jobs that employed pavers to mix concrete, directly deposit it upon the subgrade, and move ahead as the concrete was deposited. To handle the concrete from the mixing drum to the subgrade, a boom and bucket has come to be standard equipment.

For years a bucket similar to the one shown in Fig. 1 has been in general use. This type of bucket has two doors at its bottom, placed parallel to the boom. When the bucket reaches a point over the subgrade where the concrete is wanted, a workman on the grade trips the lever on the trolley carrying the bucket and opens the doors. This allows the concrete to drop out of the bottom of the bucket in a heap on the subgrade. The heap is then spaded or spread by laborers until an even layer of 6 to 7 in. is formed. As will be

COMPARATIVE ECONOMIC ANALYSIS NO. 11

Showing values for Z, V, P, and H as per formulas recommended by A.S.M.E. Committee.

It is assumed that the use of equipment No. 2 is generally accepted practice, while No. 1 is under examination for comparative economic efficiency. The factor K should be given zero value unless No. 2 is in use and would therefore be displaced by No. 1 with a corresponding capital loss.

No. 1 (designated by subscript numeral 1): One Koehring Improved Paver. Cost $7000; operating 1000 hours per year; requires 5 operators; hp. required, 40; cost of power, $21 per hp. per standard year.

Operated for Equal Production in Comparison with

No. 2 (designated by subscript numeral 2): One Koehring Old-Style Paver. Cost $7000; operating 1000 hours per year; requires 9 operators; hp. required, 40; cost of power $21 per hp. per standard year. This equipment in use 3 years. Unamortized value, $2800.

Average Values. None.

DATA REQUIRED FOR ANALYSIS

No. 1 Koehring Improved Paver		1 year = 2400 hours		No. 2 Koehring Old-Style Paver	
One		Number of units employed		One	
$*X_1$ = 41%		Per cent of year employed	(X)	$*X_2$ = 41%	
A_1 = 5%		Per cent on investment	(A)	A_2 = 5%	
B_1 = 2%		Per cent for insurance, etc.	(B)	B_2 = 2%	
C_1 = 18%		Per cent for upkeep	(C)	C_2 = 18%	
D_1 = 20%		Per cent for depreciation	(D)	D_2 = 20%	
Total = 45%				Total = 45%	
E_1X_1 =	$ 344.00	Cost of power, etc.	(E)	E_2X_2 =	$ 344.00
5000 hr. at 45 cents	$2250.00	Cost of labor	(S)	9000 hr. at 45 cents	$4050.00
20% of payroll	$ 450.00	Cost of labor burden	(T_a)	20% of payroll	$ 810.00
$I_1(A_1+B_1+C_1+D_1)$ =	$3150.00	Cost of fixed charges	(T_b)	$I_2(A_2+B_2+C_2+D_2)$ =	$3150.00
Total for 41% of yr.	$6194.00	Cost of operation		Total for 41% of yr.	$8354.00
	$7000.00	Value of increased production	(U)		
		Cost of equipment	(I)		$7000.00
		Unamortized value of equipment less resale value	(K)		$2800.00

VALUATION OF FACTORS

$A_1 + B_1 + C_1 + D_1$	=	45 %	= $A + B + C + D$
$E_1 - E_2$	$ 344.00 — $ 344.00 =	$ 0.00	= E
$S_2 - S_1$	$4050.00 — $2250.00 =	$1800.00	= S
$T_{a2} - T_{a1}$	$ 810.00 — $ 450.00 =	$ 360.00	= T_a
T_{b2}	=	$3150.00	= T_b
$U_1 - U_2$	$ 0.00 — $ 0.00 =	$ 0.00	= U
[2] $Y_1 = I_1(A_1 + B_1 + C_1 + D_1)$	=	$3150.00	= Y
I_1	=	$7000.00	= I
K_2	=	$2800.00	= K

* X is applied individually in Cases Nos. 1 and 2, hence 100 % = X

[1] Ch. Engr., Koehring Co. Mem. A.S.M.E.

[2] Vice-Pres Engrg., Economic Research, Shepard Elec. Crane & Hoist Co. Mem. A.S.M.E. Mr. Shepard prepared the comparative economic analysis (No. 11) accompanying Mr. Lichtenberg's paper.

Contributed by the Materials Handling Division for presentation at the Spring Meeting, Milwaukee, Wis., May 18 to 21, 1925, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. All papers are subject to revision.

Be sure to bring this copy with you to the Spring Meeting

SOLUTIONS

Z = Maximum Investment Which Will Return Simple Interest on Investment

[1] $$Z = \left[\frac{(S + T_a + U - E)X + T_b}{A + B + C + D}\right] - K = \$9000$$

V = Yearly Profit from Operation

[3] $$V = [(S + T_a + U - E)X + T_b] - [Y + (KA)] = \$2020$$

P = Yearly Profit in Per Cent on Investment

[4] $$P = \frac{V}{I} + A = 33.8 \text{ per cent}$$

H = Years for Complete Amortization of Investment out of Profits

[5] $$H = \frac{100\%}{P + D} = 1.8 \text{ years}$$

SUMMARY OF ANALYSIS NO. 11

Estimated actual investment required for No. 1	$7000.00
Estimated excess investment in No. 1 over No. 2, $I_1 - I_2$, or I_1	$7000.00
Estimated yearly profit from operation No. 1 over No. 2, excess above simple interest	$2020.00
Estimated value of reduced labor turnover	$ 0.00
Total	$2020.00
Estimated yearly profit from operation of No. 1 over No. 2 in per cent on investment, total	33.8%
Estimated yearly profit from operation of No. 1 over No. 2 in per cent on excess investment, $\frac{I_1}{I_1 - I_2} P$, total	33.8%
Estimated time required to amortize entire cost of No. 1 out of earnings in excess of No. 2	1.8 years
Estimated time required to amortize excess cost of No. 1 over No. 2 out of earning in excess of No. 2, $\frac{H}{\frac{I_1}{I_1 - I_2}}$	1.8 years

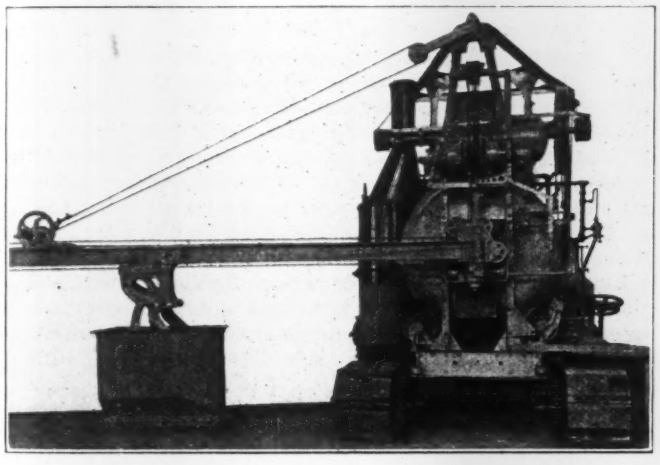

FIG. 1 PAVER PROVIDED WITH DUMPING BUCKET

noted in Fig. 2, as many as six men may be required, the minimum number being three, varying according to the consistency of the concrete or other conditions.

An improved bucket, however, has been recently developed as shown by Fig. 3. This bucket has only one door at its bottom, placed crosswise to the boom, the dimensions of the opening being approximately 4½ ft. by 10 in. When the operator of the machine has the bucket filled it is run out to the point of deposit; reversing the direction of travel automatically opens the bucket door to an extent which is regulated by adjustable stops, thus, as the bucket moves along the boom, feeding a stream of concrete over the subgrade in an even layer of the desired thickness and between four and five feet wide.

This process is repeated until the entire subgrade is covered, when the machine moves forward the length of the boom. Little or no spading is required with this type of bucket, and but two men in place of six are so employed, as shown by Fig. 3. Under favorable conditions a single laborer may perform all of the manual work required.

A simple mechanical-handling device, by placing the concrete practically into its final position, renders it possible to release within the United States several thousand laborers for other employment without increasing the investment required or other items of cost of operation, and at the same time to increase the net efficiency of operation.

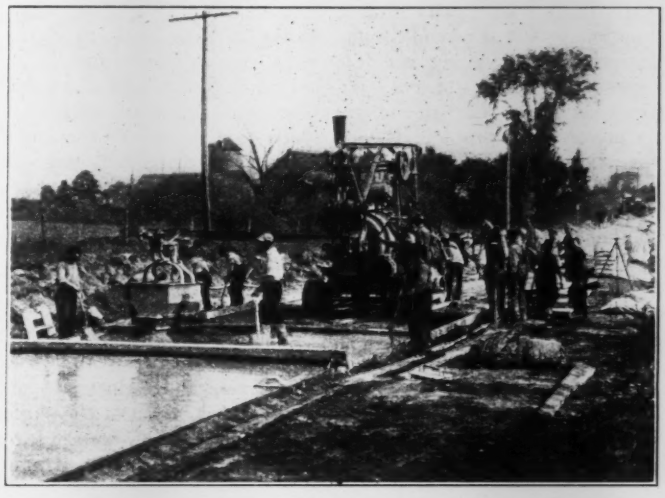

FIG. 2 PAVER OF FIG. 1 IN OPERATION

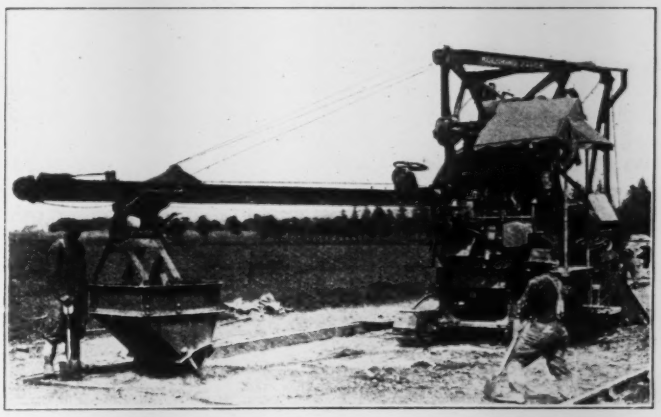

FIG. 3 PAVER PROVIDED WITH AN IMPROVED BUCKET THAT TRAVELS ALONG BOOM AND FEEDS CONCRETE OVER THE SUBGRADE IN AN EVEN LAYER

A National Apprenticeship Program

By HAROLD S. FALK,[1] MILWAUKEE, WIS.

THE shifting of the emphasis, however slightly, from production to personnel within recent years in American industry is nothing if not significant. A few years ago we were to arrive at our industrial salvation by a wholesale introduction of automatic machines and the installation of foolproof systems. This craze, however, soon had its fling. It became more and more apparent that so long as human beings are necessarily concerned in one way or another in our manufacturing and commercial enterprises, they must be given some consideration. That consideration has lately, in increased measure, taken the form of education. And this in its higher aspects is apprenticeship. Thus while American industry is more and more concerned with the problem of providing for itself a trained and skilled personnel, it has come face to face with the problem of apprenticeship.

We are just at the beginning of this movement of industrial education, but it is already apparent that a mere local application of apprenticeship along isolated trade lines is wholly insufficient to meet the needs not only of modern industry but of modern society as well. Perhaps after a somewhat detailed analysis of this present-day problem the necessity of a national program of apprenticeship in all trades and some professions will seem an obviously logical conclusion. At any rate there will be no harm in an analysis of this kind, if only because the nature of the remedy will then become clearer. However, it is our hope and intention to show the necessity of a national program of industrial education in every major trade and industrial profession in modern society. It is significant that even some of the old professions like medicine have returned to the apprenticeship method, through internships, etc.

This American workshop of ours is made up of an almost infinite number of professional, commercial, and industrial jobs. Until a few years ago we filled a considerable portion of the skilled jobs with Europeans, trained for the work. But now we are faced with the necessity of filling these same ranks with American-trained youths. This has made it necessary that we again consider the efficacy of the old method, and perhaps the only method, of training on the job, that is, apprenticeship.

Apprenticeship a Quarter of a Century Ago

Can this method be made effective under modern conditions? Let us glance for a moment, before giving our answer, at apprenticeship as it existed a quarter of a century ago. There was the small establishment which contained in its manufacturing operations all the essentials of any and every trade which it represented. The employer, who had not as yet been separated even by a private office from his employees, was, in addition to his many other duties, a father as well as an instructor to the apprentices in whom he took such a just pride. Seldom were mechanics imported via the employment office; in fact, they were almost always, if not entirely so, "made" in the plant. In other words, these establishments were producers of mechanics rather than mere users.

Let us note briefly the essentials of this rather successful training scheme: First, a "tradition" for the training of mechanics, even though this was in some measure a remnant of the European tradition, brought over by the trained mechanics, who then invaded our shores. Second, all the essentials of a complete trade or trades wrapped up in the manufacturing operations however small their scale. Third, the essentials of an adequate instructional program. The "Old Man," who for obvious reasons was interested in the perpetuation of his enterprise, made the instruction of his boys a major part of his own task. Thus instruction was bound to be effective, direct, personal, and comprehensive, though finesse was undoubtedly lacking. Hence there was present a tradition for training, the essential material for an adequate program, and the necessary effective instructional equipment.

Apprenticeship as Affected by the Changes that have Taken Place in Modern Industry

And now with this in mind let us glance hastily at the transformation that has taken place in modern industry. Two elements have entered into present-day industrial life that have changed almost completely this whole problem of industrial education. Specialization of operations and division of labor have atomized our industrial life and broken down our major trades and professions to such an extent that but few of our manufacturing establishments are able to present complete and adequate programs for the training of the skilled personnel necessary to vitalize our industrial life.

As a result but few of the larger industrial establishments in any community are capable of presenting adequate training programs. These in turn have found it impossible, if indeed they attempted at all, to train a skilled personnel sufficient for their entire community. The smaller establishments, whose operations under present conditions comprise but a portion of the trades they represent, have long since discovered an insurmountable obstacle to training apprentices. They were unable to interest young men in a formal apprenticeship because it was impossible for them to present an adequate training program.

Thus with the burden shifted to the few larger plants in any community, apprenticeship has dwindled more and more. And the tradition of training has gradually faded until at present the term apprenticeship has little meaning, unless it be an odious one. These two factors, namely, lack of a tradition and lack of material for adequate programs of industrial education, have operated powerfully to destroy even the semblance of a possibility of making apprenticeship effective in modern industry.

There are of course exceptions. But we are here concerned with a general condition which is probably proven best by the exceptions. American apprenticeship, if it can be so designated, is distinguished by a few outstanding examples the country over. But there is not an industrial community in America today that is self-supporting or solvent in its personnel phase. And the vitality of our industrial life must be judged by the solvency, in this respect, of our individual communities and not by a few individual plants.

What Does Industry Offer the Young Man Today?

It may not be amiss to consider this rather sad state of affairs from another side. We have glanced, as it were, at the situation as it exists in our manufacturing establishments. Let us glance for a moment beyond these walls into the life that surrounds them.

Here is a young man who has completed his formal education and is prepared to enter upon his life work. What does he face? An industrial life to him is completely disorganized as regards the vocation it has to offer and the jobs by means of which he might attain, consciously or otherwise, to some definite objective. Our industries are characterized more by figures of production than by trades and occupations. He knows of one concern that it produces so many *things* a month, of another that it turns out so many *tons* of material. But he has yet to learn what trades and professions are involved in the making of these things and the producing of these tons. And perhaps for the most part industry itself is unconscious of the essential vocational content of its operations. Our young man has come into an unorganized life in which he must both determine for himself his own vocation as well as the proper routine whereby he can arrive at his vocational objective.

The very complexity of modern industry makes it seem a hopeless task to determine the essential vocational lanes by means of which a young man can find his way through to some definite goal. And indeed there should be little wonder in this, since it is a matter of conjecture and experiment even among vocational experts. The essential trades and professions have been broken down into such small fragments that it has become a real puzzle to piece them together into a composite and harmonious whole.

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[1] Vice.-Pres. and Works Mgr., The Falk Corporation. Mem. A.S.M.E.

Contributed by the Committee on Education and Training for the Industries, for presentation at the Spring Meeting, Milwaukee, Wis., May 18 to 21, 1925, of The American Society of Mechanical Engineers. All papers are subject to revision.

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Alongside of this problem, and, undoubtedly as a result of it, has grown a rather universal disregard for true vocational training and education. All strata of society are more or less involved in the abandonment of this idea. Our formal educational system has come to ignore it quite completely. Scarcely anywhere is vocational training, industrial education, or apprenticeship a vital concern in the lives of the American people.

In thus stating the problem we are in no wise concerned with the placing of the blame. It has probably and undoubtedly come as part and parcel of the evolution of modern industry. Moreover to fix the blame would be of little benefit. It should be our main concern to remedy it as well and as quickly as possible.

Requisites for an Adequate Program of Industrial Education

To make effective, therefore, an adequate program of industrial education that will meet our present needs we must have, first, the materials at hand that will justify a complete and full scheme of training, second, effective instructional equipment, and third, an adequate tradition that will bear along and give moral support to this program.

Upon this foundation we shall build our program for an adequate apprenticeship. In order that each industrial community can become self-supporting in its personnel aspect, all establishments in those communities must unite to supply the training that is necessary. But the majority of the smaller establishments are unable, alone and separately, to present a real training program. There must be a grouping of these plants along trade lines in such manner that the groups can present adequate and effective programs of industrial education. This must become a community affair in which all of the interested elements do their proportionate share in this scheme of training. There must be a community organization to organize, establish, and coördinate groups that can present adequate programs of training.

Proper vocational education of the related type that must necessarily accompany true apprenticeship must also be established on a community basis. All elements that are and should be interested must give the proper support to a centrally located institution which can provide for them the only possible means of adding the related classroom instruction so essential in a formal apprenticeship. Small industrial establishments under the very best possible circumstances would be unable, even if they desired, to add this essential element of the training. The larger establishments could ill afford to attempt it individually if only because of the ill effect that such an arrangement would have upon a community program. The vocational educational institution must be the rallying ground for this community enterprise. In this way only can all of the industrial and commercial interests be adequately served in proportion to their just needs.

Milwaukee's Experiment in Vocational Education

Milwaukee is at present engaged in carrying on an experiment of this kind. The metal-trades industries have united on a community basis to promote an adequate program of industrial education. Coöperatively they are making this community self-sufficient and independent in its supply of skilled mechanics.

This group of trades early realized that it would be impossible to make a program of industrial education wholly effective if but few of the larger plants were engaged in these training activities. Hence training groups were formed in which smaller organizations were arranged about the larger in such manner that the groups were able to present a complete and adequate program of training. Thus, apprentices are exchanged between smaller and larger plants according to a prearranged plan.

A district director has been engaged to coördinate the activities of the various groups, to promote apprenticeship whenever necessary, and to gather together all the ends of the multitudinous details that are always a part of a large community project of this kind.

Under the auspices of the community metal-trades organization and at the direction of the district supervisor, an effective promotional program has been made a part of the annual activities. Inspirational gatherings of apprentices, parents, and employers have been held which culminate in an annual dinner entertainment. At the last of these more than a thousand Milwaukee metal-trades apprentices and employers were present.

The Community Program Closely Related to the Public-School System

This community program includes a very close and definite relationship to the public-school system, particularly the local vocational school. This institution has become the hub about which this whole training scheme revolves. Not only do apprentices attend the vocational school part time during their apprenticeship, as required by law, but they also attend full time during a part or all of their probationary period. These full-time classes have given a prestige to apprenticeship among young prospectives to an extent that no other arrangement could possibly have done. Beyond this, however, the vexations incident to the necessary vocational-guidance work among probationary apprentices has been removed from the shop foremen, who are already sufficiently burdened with certain portions of this training work.

Thus the part-time school has become a very essential and necessary instrument in the promulgation of this plan. Without it the smaller plants would be unable to give any related trade training. Without it the larger plants would have the whole community program upon their hands and would have an onerous burden upon their shoulders which could be more efficiently dealt with by the vocational school in conjunction with the above organization. The Milwaukee Vocational School under the direction of Mr. R. L. Cooley cannot be given too much credit for whatever success the Milwaukee plan has achieved. Through its leader it has not only administered efficiently but coöperated magnanimously.

Milwaukee has ceased to talk apprenticeship in terms of the individual plant. It considers the problem only from the community viewpoint.

A National Organization to Promote Apprenticeship Needed

But Milwaukee realizes that it cannot stand alone. If its work is to endure and enjoy a permanent success, each and every American industrial community must carry on a similar community apprenticeship. In other words, a national program is essential.

Unless this work be conceived on a national basis and a national organization be endowed with the powers to promote, administer, and traditionalize apprenticeship, an isolated success like that of Milwaukee will become temporary and gradually vanish. Every American industrial community must be made an intimate part of this scheme of industrial education. In no other way can we as a nation sustain our industrial supremacy. In no other way can we as a nation—and this is more fundamentally important—be perfectly fair and just to each young generation as it passes out into the world of work and accomplishment. We need a national organization and a national plan to inaugurate a promotional program such as will once and for all place apprenticeship in its proper place in our economic order. Some years ago, in 1912 to be exact, a safety congress that convened in Milwaukee burst the bonds of provincialism and started what at the present time has become the greatest national advertising campaign in history. From Milwaukee the inspiration to a national effort for universal safety went forth and became shortly not a community but a national crusade.

"Safety" has become a household slogan. "Apprenticeship" must become a similar slogan. We must make of our efforts through a national body, properly endowed and supported, a nation-wide crusade that will enkindle this light of the new industrial education in every American community. We need a national organization to *promote* apprenticeship.

We need a national organization with a national program to administer apprenticeship. This burden of training must be properly apportioned among our communities. Data, and educational and instructional matter must be gathered and assimilated, to be used again where its effectiveness will be greatest. A national clearing house of this kind is indispensable. The rules of the game must be laid down and administered so that all can act justly and fairly in carrying on their share of the work. Such reserve of strength as a national organization can encourage the faltering, strengthen the weak, convert the unbelieving, and administer the burden justly among those who are active.

THE TRADITION OF APPRENTICESHIP NEEDED AGAIN IN MODERN AMERICAN INDUSTRIAL LIFE

But above all and foremost do we need to revitalize the tradition of apprenticeship in modern American industrial life. Not only must our industries prepare a planned life for the young people they receive, but the parents of these young people must come to regard a planned life as of the highest importance. Apprenticeship must be for them but a continuation of the education of their children. It must in fact become as important as an education and as a vital and integral part of it. Unless this be made the objective of a national program, it must fail. Its moral force, its reserve of power, and its prestige can force the attention of all elements in present-day American society to this problem of industrial education. In this way only can the tradition of apprenticeship be reëstablished and revivified.

Milwaukee has achieved some success with this program of apprenticeship. All members in its community have begun to give that place to apprenticeship in their lives which it justly deserves. The metal-trades group has made more than a beginning toward the accomplishment of this program. Strong traditions of prejudice that have almost strangled certain trades have been broken. Mothers and fathers are beginning to consider apprenticeship quite as necessary as a formal education. But unless Milwaukee can be supported in this work by every American industrial community, it can never hope for final success. Until apprenticeship in all lines to which our American youths are admitted is generally and universally established upon a national basis and promoted, organized, and supported by a national organization, Milwaukee can ill afford to, nor does it, glory in its apprenticeship achievements.

Elimination of Unnecessary Fatigue in Industry

Abstract of Report of Committee to the A.S.M.E. Management Division

BY PROF. GEORGE H. SHEPARD,[1] PURDUE UNIVERSITY, LAFAYETTE, IND.

THE last report to the A.S.M.E. on fatigue elimination was made at the Annual Meeting in 1923 by the late Major Frank B. Gilbreth. Since that time there have been no noteworthy developments. Dr. Lillian M. Gilbreth has a vast amount of data on the subject, but they have not yet been analyzed and classified.

The British Government has organized an Industrial Fatigue Research Board to carry out investigations with a view to finding out the most favorable hours of work and other conditions of employment applicable to industrial occupations. Reports of this Board are often useful in the solution of industrial problems, and can be obtained from H. M. Stationery Office, 28 Abingdon St., London, S. W. I. It is urged that the A.S.M.E. suggest to the American Engineering Council that it point out to the Secretary of Commerce the need for similar governmental activity in America.

Quantitative data regarding the effect of fatigue on production are lacking, although to the engineer this phase of the subject is of great interest. It is well known that improper seating, nervous disorders growing out of unfavorable working conditions that bring about fatigue, and the serious eye strains caused by faulty illumination, all result in a very appreciable drain on productive capacity. Eye fatigue will be studied under standardized conditions in extensive experiments contemplated by Dr. C. G. Brandenburg, Professor of Educational Psychology, C. A. Brown, C. T. Shuh, and the writer at Purdue University during the next year.

Temperature and humidity of the air, and correct ventilation are important elements in reducing industrial fatigue. The katathermometer has been invented by Dr. Leonard Hill to measure the cooling power of the air on the human body, since this action has a decided influence on the problem of ventilation.

The British Industrial Fatigue Research Board have started an investigation into the design of machinery in relation to the requirements of operation. In the past, machines have been designed from the mechanical rather than from the manipulative aspect.

Research on muscular fatigue, and on the necessary frequency and duration of rest periods to overcome fatigue, is being continued at Purdue University.

Prof. Henry J. Spooner, of London, reports that he is making a special study of noise as it affects industrial fatigue. He states that the National Physical Laboratory during 1924 equipped special rooms for the study of sound and developed special apparatus for testing. Particular attention has been devoted to an investigation into the sound-absorptive values of different kinds of materials used in building construction, and equipment for large-scale tests is being provided. The acoustic properties of buildings are receiving attention. Photographic studies of sound waves are also in progress.

Professor Spooner further predicts that before long noise will receive as much attention from hygienic authorities as noxious fumes, lighting, heating, ventilation, and sanitation, as an important factor in industrial activity.

The coöperation and interest of the A.S.M.E. in the effort to cut down the waste in industry that comes from unnecessary fatigue is greatly appreciated by the Committee of the S.I.E.

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Factors Concerning the Economics of Shopping Steam Locomotives

The Folly of Continuing Obsolete Designs in Service—Trend of Unit Costs Since 1910—Effect of Specific Shopping Policy on Cost of Repairs—Bearing of Utilization of Power on Shopping Policy, etc.

By L. K. SILLCOX,[1] CHICAGO, ILL.

THE successful manufacturer must know the units of cost to produce his wares, for upon their application depend his profits. The universal adoption of more or less detailed cost accounts in both large and small establishments and the greater scrutiny given to them by owners and managers are real evidence of the value of such knowledge and the necessity therefor. Knowing that such information is successfully determined and applied in the commercial world, surely it can be as effectively established and employed in the matter of railroad-locomotive maintenance and be the basis of executive policy with a view toward assisting the average motive-power man in carrying out evident possibilities for economy and an effective procedure at least cost.

Economies are of two kinds: internal economies which can be carried out independently by the mechanical officer of his own motion; and the much greater economies which management, as a whole, can only make possible, based on current studies as to policies and possibilities. Perhaps one main reason why the justice of the principles above stated is not more readily conceded is to be found in the fact that it is oftentimes regarded as exceptional. The truth would rather seem to be that railroads are only typical of the more modern business organizations, and should seriously study, regardless of known obstacles, what the possibilities really are, and then constantly endeavor, item by item, to make progress along fundamental lines; all of which, for the purpose of our discussion, revolves around the question of the proper utilization of motive power. In truth, though we have emphasized the point of management policy and imagined an executive fixing a complete system, yet no one man, and indeed no combination of men, could evolve a best method off-hand from the foundation. It can only grow gradually, developing here and changing there, in line with economy, as the territory requires or the nature of the traffic and the competition in attracting it become an issue. But the guiding idea of management having a proper and stable policy remains the same throughout.

The serious question we have before us is the necessity of deciding upon an accurate unit of measure. We need correct and simple facts, susceptible of a clear and concise understanding on the part of all concerned, and clear as well as quick application by railway officers charged with the duties of maintenance and operation. The expenditure for locomotive maintenance so far as it is caused by frictional wear and tear will evidently increase in direct proportion to the strain of the work imposed upon the locomotive; at the same time, to the extent it represents outlay for replacement of parts, obsolete though not worn out, so far it is independent of work done. Any plan used in the shopping of power involves complete consideration as to necessary maintenance and the effect from characteristics of service, as well as details of motive-power construction, age and availability of shop, roundhouse facilities, etc. Maintenance may be defined as the upkeep or replacement of parts as due, based on individual consideration of each item with respect to limits of wear, strength requirements, and reliability factors. The accounting for the cost of maintenance varies with the type of property. Maintenance of locomotives, for instance, when finally accumulated for the year and reported as required by the Interstate Commerce Commission's classification of accounts, embraces not only the labor and material applied together with the allocation of direct overheads, such as shop expense, power-plant distribution, store expense, etc., but the depreciation and retirement charges. The carrier has the option of determining the rate at which depreciation shall be charged and accumulated currently, but the general principle is to apply a rate somewhat consistent with the estimated total life after deducting the estimated amount of salvage recoverable when the unit is dismantled. Any depreciation which is not sufficient when a locomotive is retired is made up by retirement charges applied against the locomotive-maintenance account at the time of dismantling; therefore equipment maintenance is charged currently with paying off the investment as well as overcoming wear and deterioration. The maintenance of fixed structures, such as bridges for instance, is charged currently as actually incurred, no depreciation being accumulated during the life of the bridge but the entire investment being charged off to operating expenses at the time of final retirement. Taking these facts into consideration, therefore, a fixed structure, having a longer life than equipment, requires a lesser rate of renewals, and a bridge costing new $64,000 as compared with a new locomotive costing the same amount will incur a final average charge for maintenance and retirement of approximately 4 per cent as compared with approximately 15 per cent per year for a locomotive. However, in considering the subject as a whole from an equipment standpoint, we are able to segregate the direct repair cost from other charges, the repairs being confined to a sub-account in the classification, which involves labor plus shop expense, and material plus store expense. It is a fact that in not a few instances much of the expenditure for locomotive maintenance, as reflected in the accounts, is occasioned from patching up old construction, even though in some cases this does extend to the point where the actual repair cost, as renewed, exceeds the major portion of the value of the unit as renewed and, consequently, is recapitalized; in which event, nevertheless, the retirement expense must be carried in maintenance.

The Folly of Continuing Obsolete Designs in Service

A close study will very often indicate the folly of spending large sums per unit to continue obsolete designs in service for long periods when the same amount would be more than sufficient, as an initial cash payment, for an up-to-date efficient design of greater capacity and less cost to operate or maintain. Let us test this by imagining a concrete case. Assume that a passenger engine fifteen years old and originally designed to handle a nine-car train is now required to carry fifteen cars on the same schedule, resulting in a heavy maintenance cost due to frame breakages, racking of machinery, valve motion, running gear, etc. Then it becomes a question of not only maintenance but investment. If the original unit was of 40,000 lb. tractive effort and was co ing an average of $9000 per year to maintain with a relatively low record of 3000 miles per month, then it would seem proper to consider a new type of power, say, with 50,000 lb. tractive effort which would afford 5000 miles of service per month and yet not cost more than $5000 per year for maintenance, making a saving of approximately $4000 per year in maintenance cost and increasing the performance 66 per cent. This would justify making a change in power even though the original unit might have cost $30,000 and the new unit would cost $60,000. The original unit involved a maintenance cost of $9000 per year plus a depreciation charge of $750, or a total of $9750 as compared with an estimated maintenance cost of $5000 per year for the new unit plus $1500 depreciation charges or a total of $6500, making a saving in the new unit of $3250 per year, to say nothing of additional savings in fuel and transportation expenses. At 6 per cent this recovery would represent an investment of $54,000, or almost the cost of the new unit, but if this were done on a large scale then the amount of work would be performed with 66 per cent of the number of new units as compared with the number of old units, and thus the change would be justified. It should be understood, however, that

[1] Mech. Dept., C. M. & St. P. Ry. Co. Mem. A.S.M.E.

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passenger service is more constant than freight, so that this example is not presented with the idea that such a reduction in the number of units is possible in passenger service, but is more applicable to freight service. The extent to which carriers are developed along this line reflects in a general way upon the maintenance policy and the cost. Obsolescence of locomotives is a very indefinite measure and its application, in general, is entirely according to local conditions. A locomotive will grow obsolete and costly to operate even if it only remains standing, and this same factor will become of increased importance if it is kept constantly in operation for a long term of years without substantial improvement to care for advanced practice, due to transportation losses from excess fuel consumed or questionable reliability in service affecting train move-

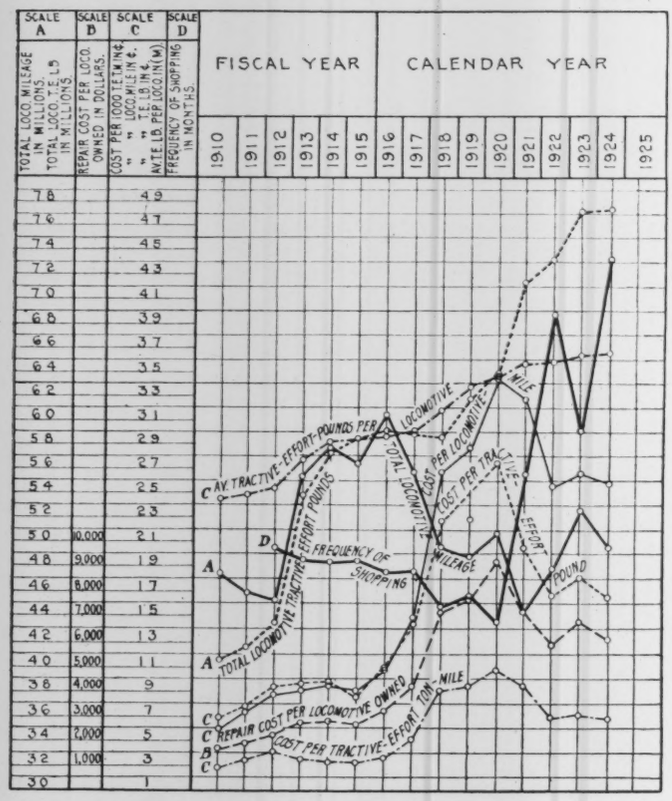
SCALE A
TOTAL LOCO. MILEAGE IN MILLIONS. TOTAL LOCO. TR. L.B IN MILLIONS
SCALE B
REPAIR COST PER LOCO. OWNED IN DOLLARS.
SCALE C
COST PER 1000 TR. MI. & " " LOCO. MILE IN ¢. " " TR. LB IN ¢. AV. TR. LB. PER LOCO. IN (M).
SCALE D
FREQUENCY OF SHOPPING IN MONTHS.
FISCAL YEAR
CALENDAR YEAR
1910 1911 1912 1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925
78 76 74 72 70 68 66 64 62 60 58 56 54 52 50 48 46 44 42 40 38 36 34 32 30
49 47 45 43 41 39 37 35 33 31 29 27 25 23 21 19 17 15 13 11 9 7 5 3 1
10,000 9,000 8,000 7,000 6,000 5,000 4,000 3,000 2,000 1,000
AV. TRACTIVE-EFFORT-POUNDS PER LOCOMOTIVE
TOTAL LOCOMOTIVE TRACTIVE EFFORT POINTS
FREQUENCY OF SHOPPING
COST PER LOCOMOTIVE MILE
COST PER TRACTIVE EFFORT POUND
TOTAL LOCOMOTIVE MILEAGE
REPAIR COST PER LOCOMOTIVE OWNED
COST PER TRACTIVE-EFFORT TON-MILE
A
B
C
D

FIG. 1 DATA OF STEAM-LOCOMOTIVE REPAIRS AND PERFORMANCE, C. M. & ST. P. RY., 1910–1924

ments. For this reason it would seem a wise plan to obtain all the mileage possible from locomotives, so that the time when they are worn out may arrive at least as soon as the stage when they become out of date.

POLICY USED IN SHOPPING POWER A CENTRAL FACTOR

The same idea of promoting efficiency may be applied to the method employed in shopping locomotives, all of which resolves itself largely into a consideration of the program or the plan employed as best suited by any given administration. There are many elements in the matter of executive policy which go to make a relatively high or low maintenance cost, and the method of shopping power is one of the primary features to be considered. It is possible to hold different opinions as to the attitude which it is proper to assume, but aside from the variation in the characteristics of power owned, when comparing the performance of a number of administrations it may be said that the policy used in the matter of shopping power becomes a central factor and may be considered as the hub of the force at play. The range of possibilities in any given case may be easily determined from a study of practices obtaining on various systems, but, as a matter of fact, there are two extremes, with many variations between them. One is what may be termed the "high-frequency-shopping" and the other the "low-frequency-shopping" policy. The high-frequency-shopping policy is that based on running locomotives through shops with an anticipated service of from twelve to fourteen months with a minimum of roundhouse attention. The low-frequency-shopping policy is that based on running locomotives through shops with the idea of having a service of 24 months or more and with a greater degree of roundhouse attention to attain this length of service. Vital elements in determining such a policy are the relation of the number and size of locomotives owned to the business handled, the road conditions for hauling heavy- or light-tonnage trains, the topography of the country traversed, the distribution of industrial centers, the presence of large terminals, the spacing and capacity of roundhouses, the distribution and assignment of power, the placement of forces as between roundhouses and back shops, the rapidity with which mileage is run out, and particularly the roundhouse and back-shop facilities for handling certain classes of work. Furthermore, where a railroad has back shops of an obsolete character it is practically as well off doing its work in roundhouses, and it may be found helpful under such conditions to construct small modern back-shop facilities at critical points to care for division requirements without increase in overhead expense.

TREND OF UNIT COSTS SINCE 1910

The results obtaining under the two extremes of policy mentioned have been observed for a considerable period, and it appears that policy is largely governed by local conditions rather than local conditions being governed by policy. The road with which the author is connected has had experience under both plans, and just as a case in point, the general results obtained will be stated. Prior to 1921 a high frequency of back-shop repairs was employed, but after considerable study the plan was changed to a low frequency of repairs. The trend of unit costs, etc., both prior and subsequent to 1921, is illustrated in Fig. 1. This chart is a graphic illustration of the results obtained under these two extremes of policy, affected, of course, by the price trend of labor and material in the meantime. The lines plotted represent three general groups, one indicating the growth and size of units maintained, another the various unit costs of maintenance, and a third the frequency of back-shop repairs. The growth of property maintained is represented by the dotted line *A*, which indicates the total tractive-effort pounds owned from 1910 by years to the end of 1924. This growth was not all in the nature of new equipment but represents power added by the acquisition of subsidiary and leased lines as well as some new equipment, and to that extent the growth line should not be confused with the rate at which new equipment might have eliminated obsolescence. This very fact has a marked bearing on the cost of maintenance, as the total growth consisted of approximately as many of the smaller and older locomotives as of the acquisition of the larger and newer types. As to whether or not this extension of property was consistent with the growth of business naturally depends upon how the acquired lines may have increased the amount of business in relation to the amount of property. It is not desired to elaborate here upon the principles of the proper rate of growth of property, but merely to state that the method of computing the proper growth would be to determine the gross revenues per locomotive owned, affected somewhat by the characteristics of the lines added as to their ability to function on a high or low unit train-tonnage basis. Nevertheless the growth of property represents a serious problem in the matter of having back-shop development keep pace with it and of getting continuous use from power. Fig. 1 also shows the increase in the average size of locomotive expressed by the mean tractive-effort pounds per locomotive owned. The size of locomotives is an element in the unit cost of maintenance, and it will be noted that this figure increased from approximately 24,000 tractive-effort pounds per unit to 36,000 in 1924, or approximately 50 per cent. The chart is confined to steam locomotives only, electric locomotives being a separate and distinct problem. It is not possible to state whether the growth in locomotive ownership increased more or less than the revenues or the average train load, as these data are not available from the subsidiary and leased lines.

The feature in Fig. 1 which is deserving of closest study is the line *D* representing the frequency of back-shop repairs. This is arrived at by dividing the total yearly classified-repair output into the total owned throughout the year, which expresses the number

of years between shoppings thus developed, and this of course varies from year to year according to the difference in the number of locomotives owned or used and the output. This is based upon a classification of repairs instituted during federal control and is translated back to 1912. This classification runs as follows:

CLASS 1: New boiler or new back end. Flues new or reset. Tires turned or new. General repairs to machinery and tender.

CLASS 2: New firebox, or one or more shell courses, or roof sheet. Flues new or reset. Tires turned or new. General repairs to machinery and tender.

CLASS 3: Flues all new or reset. (Superheater flues may be excepted.) Necessary repairs to firebox and boiler. Tires turned or new. General repairs to machinery and tender.

CLASS 4: Flues part or full set. Light repairs to boiler or firebox. Tires turned or new. Necessary repairs to machinery and tender.

CLASS 5: Tires turned or new. Necessary repairs to boiler, machinery, and tender, including one or more pairs of driving-wheel bearings refitted.

General repairs to machinery will include driving wheels removed, tires turned or changed, journals turned, if necessary, and all driving boxes and rods overhauled and bearings refitted, and other repairs necessary for a full term of service.

Running repairs unclassified.

Suffix "A" to any class of repairs will indicate that the repairs are required on account of accident.

"B" will show the initial application of stoker.

"C" will indicate the initial application of superheater.

"D" will indicate the initial application of outside valve gear.

"E" will indicate locomotive was converted from compound to simple or from one type to another.

Mallet locomotives will be indicated by a star following application.

Locomotives receiving Class 1, 2, or 3 repairs must be put in condition to perform a full term of service in the district and class of service in which they are to be used.

Class 4 repairs not less than $^1/_2$ term.

Class 5 repairs not less than $^1/_4$ term.

It may be generally conceded that the above is not sufficiently specific to be a complete measure of output since the divisions are not based on work units to a great enough degree to permit of judging shop output in detail.

COST OF REPAIRS PER 1000 TRACTIVE-EFFORT TON-MILES

The variation in the trend of line *D* is entirely dependent upon the allotment of labor and materials available for maintaining equipment. The shopping frequency increased gradually from 1912 to 1920, and during the latter year locomotives were going through at the rate of once every 14.28 months. In 1921 a committee was appointed to report upon the economics of shopping power, as a result of which it will be noted there was a radical change in the frequency of back-shop classes of repairs subsequent thereto. This study related particularly to the situation existing on the Chicago, Milwaukee & St. Paul Railway and is not offered as a criterion for the reason that other conditions often determine whether or not such a policy is applicable to any but a specific case. The frequency of shopping trend, expressed both in years and in months between shoppings, was as follows:

Year	Years between shoppings	Months between shoppings
1920	1.19	14.28
1921	2.20	26.40
1922	3.30	39.60
1923	2.50	30.00
1924	3.70	44.40

The change in plan necessarily brought about some modification in the distribution of machine tools and facilities in back shops and roundhouses. Great care had to be employed to avoid deferred maintenance under such a transition because of the high cost incident to overcoming deferred maintenance promptly and adequately were this condition to have obtained. The roundhouses were partially equipped to do the necessary machinery and running repair work and in some cases rather heavy boiler work so as to properly maintain the power for longer periods, some of the facilities being transferred from the back shops to the roundhouses. The back-shop forces were reduced in proportion. Prior to the change all judgment as to months good for, miles to be run between shoppings, etc. was based on the theory that locomotives were good for a term of 12 months only, and consequently a large amount of data was prepared to show that this attitude was not in keeping with the operation of the property and therefore should be adjusted to the new method. Prior to 1921 there was no specific application of the plan of assigned mileage to be used as a basis for shopping power. This method was put into use at that time and a statement prepared showing the expected mileage to be run out after each classified repair, divided according to types of power. It is important that the same mileage should not be applied to the same type of power regardless of where or how used, and in this respect an assigned mileage for each class of service, type of power, and for each division instead of for the system as a whole is necessary in practice, otherwise classified repairs will be made in roundhouses, but not so reported, in order to avoid breaking the mileage. The method of breaking mileage varies throughout the country, but this does not affect the data used here. As to the results obtained from this change of plan, it should be understood that there have been some wage and material price variations since 1920, but these adjustments account for approximately 14 per cent of the reductions attained. The cost trends on the chart merely indicate the actual reductions, with no separation between fluctuations in the cost of material and labor, shop efficiency, etc. The cost per locomotive-mile during the high-wage period of 1920 reached 34 cents when the shopping frequency was 14.28 months, but after the frequency of back shopping was reduced the cost steadily declined and in 1924 was less than 26 cents. This represents a reduction of approximately 24 per cent. The cost per tractive-effort pound was reduced from 27 cents in 1920 to 16.5 cents in 1924, or 39 per cent. The cost of repairs per locomotive owned was $9300 in 1920 and $6000 in 1924, or a reduction of 35 per cent. The cost per thousand tractive-effort ton-miles was reduced from 1.075 cents in 1920 to 0.676 cent in 1924 or 37 per cent. In the meantime the average size of locomotives increased 6 per cent. The method of measuring the cost of repairs per tractive-effort ton-mile was to take the tractive-effort pounds owned, reduce them to tons, multiply by the miles run in thousands, and divide this into the cost of repairs, Account 308. (This unit should not be confused with ton-miles hauled; it is entirely independent of the rate of grade or curvature and is merely the force of one ton acting parallel with the rails and at the circumference of the drivers through a distance of one mile). Expressed as an equation,

$$D = \frac{C}{\frac{A}{2000} \times \frac{B}{1000}}$$

where

A = total tractive-effort pounds owned
B = total locomotive miles run during year
C = cost of repairs, Account 308, or exclusive of depreciation, retirement, etc.
D = cost of repairs per 1000 tractive-effort ton-miles.

As previously stated, there were reductions in wage rates and cost of material in this period, so that the entire reduction is not to be credited to the change in plan referred to.

Finally, we have seen that this principle of shopping locomotives is in no sense special or peculiar. As to whether or not a policy as outlined could be taken as a criterion, it would be difficult to state. The plan was adopted for the C. M. & St. P. system because it appeared to be properly applicable. It is a matter of interest in this connection, however, to make a study of ten carriers where there is a wide range of policy, using the same units outlined above. The value of the units used cannot be considered as entirely intrinsic and for that reason the method employed should not be considered as absolute. The chart of Fig. 2 is offered as a result of a study of various carriers, some having a high-frequency and some a low-frequency method. In plotting the data, scales were used merely to throw relative items together in order to indicate those which run in a certain ratio and those which run inversely. The horizontal scale is the average tractive-effort pounds per locomotive owned—to show the size maintained. The data are based on 12 months in 1924.

Another point may be observed. In the matter of performance the average miles per locomotive run per year is given by line *A*. This shows a difference in performance which does not follow relatively the variation in size of power, indicating many degrees in intensity of use, etc. The mileage ranges from 20,800 to 28,500

per locomotive per year. The carrier with the largest size of power made practically the same mileage per locomotive as the one with the smallest size of power shown on the chart, whereas those administrations with locomotives of a size ranging between the two extremes made less mileage per locomotive. This may be considered an element of performance and demand characteristics of the lines involved. In this case the highest mileage was 37 per cent greater than the lowest shown.

The cost per locomotive-mile as shown by line *B* is low for the carrier having the smallest size of power, being less than 17.5 cents, and is high for the one having the largest size of power, the upper range being a little less than 30 cents per locomotive-mile.

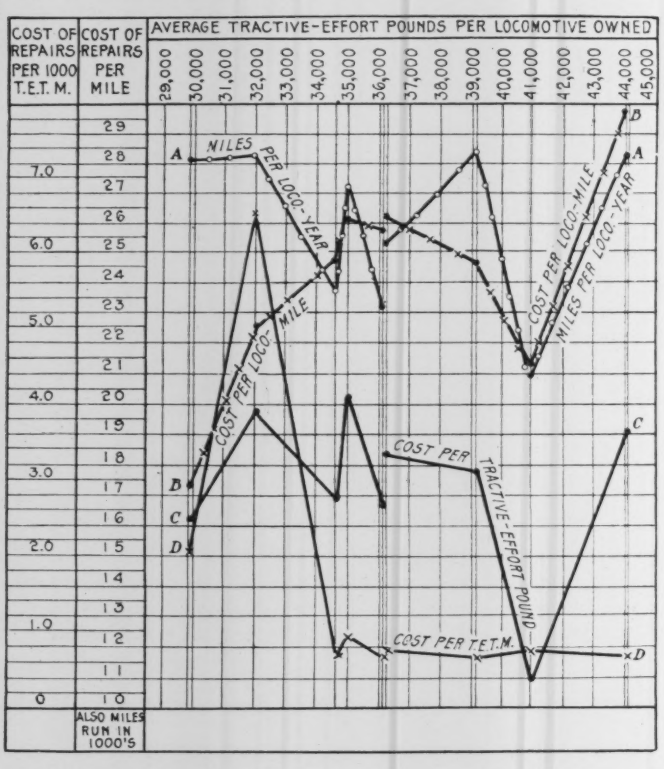

FIG. 2 COMPARISON OF COST OF MAINTAINING STEAM LOCOMOTIVES CONSIDERING AVERAGE SIZE, AVERAGE MILES, AND COST OF REPAIRS PER MILE PER TRACTIVE-EFFORT POUND AND PER 1000 TRACTIVE-EFFORT TON-MILES

The average size of power expressed in tractive-effort pounds was 47 per cent greater in the largest average size as compared with the smallest average size, whereas the cost per mile was 71 per cent greater for the larger than the smaller power, so that it may be said that in this case the cost increased one and one-half times as the unit size of power increased. This figure is not in itself entirely significant.

The cost of repairs per tractive-effort pound being a measure of size only, does not run in direct ratio with the increase in size. It will be noted that while the smallest size of power has the lowest cost of repairs, the largest size of power does not have the highest cost of repairs, both being exceeded by carriers having locomotives of intermediate capacities. The composite factor of cost of repairs per thousand tractive-effort ton-miles, consisting of the size and mileage, ran somewhat inversely with the capacity of power owned, with variations in the intermediate sizes. Here it is interesting to note that the smaller size of power cost more than the larger, the result being due in this case to the carrier with the larger power running about the same mileage per unit as the carrier with smaller power.

There would be no profit in going further into details, since these data are presented merely as a matter of comparison and to illustrate the fact that it is most difficult to establish a criterion or a specific policy which is applicable in all cases. Road characteristics, density of traffic, and many other elements must be considered in any calculation that aims to be complete and conclusive. However, in general it has been found that carriers using large-size power have a fairly high frequency of back shopping, which is of great interest in this study because it is evidence, for the most part, of intensive use and a more or less uniform power demand. Thus far the frequency has been stated in terms of time only. It is affected very largely by the rapidity with which mileage is run out, and therefore, in a general way, reflects whether carriers are long or short in their power ownership.

These data indicate that as the average tractive-effort pounds owned increases, the cost of repairs per mile increases in a rather definite way; that the average miles per locomotive run and the average cost of repairs per tractive-effort pound have the same range characteristics; and that the average cost of repairs per thousand tractive-effort ton-miles varies somewhat inversely with the average tractive-effort pounds per unit owned, with intermediate fluctuations.

In using tractive-effort ton-miles as a unit of measure in this case it should be understood that there is a variable feature in the actual amount of capacity employed as compared with the maximum available. The larger units may or may not exert as great a percentage of the total tractive effort as the smaller units, and to the extent of this variation this measure must be considered only with the knowledge thereof. Here again maximum or ruling gradients, scheduled tonnage, etc. are factors showing how near the capacity available is utilized as compared with the maximum at hand, and the studies given here are made only with the intention of indicating that, regardless of any units of measure used, there are local conditions which determine the differences in the showing made and that these are usually found to justify the outcome. The tabulations are therefore presented with the necessary reservations as to limits of their scope. This unit of measure does not include the work performed, that is, the tonnage hauled, which if added would doubtless give trends differing from those shown on the chart; but the tonnage hauled is a matter of record in freight performance only, whereas the data thus far considered apply to all classes of power. Statistics are now available to show the gross ton-miles per freight-train-hour, which is a fair measure of locomotive performance when considering the average size as well as the number of units employed. This reflects efficiency in train handling as well as corresponding utilization of power, and where there is prompt turning in roundhouse care and running repairs fewer locomotives may be used for a given traffic, thus building up a reserve and maintaining a proper shopping period. It is necessary, of course, to apply such data to road engines only, and this can be done with the information at hand. The variation among carriers in such performance is quite extreme, some having as high as 26,000 and others as low as 12,000 gross ton-miles per train-hour. This difference is far greater than the average size of power and other influencing factors such as grades, curvature, signal stops, etc. would indicate, and leaves open to study the question of greater development along the line of utilization of power and consequent shopping methods.

EFFECT OF SPECIFIC SHOPPING POLICY ON COST OF REPAIRS

Just what effect the specific policy followed has upon the trend of the cost of repairs is not thoroughly ascertainable, but it would seem that a minimum cost may be expected when it has been definitely established that a proper balance between classified and running repairs has been arrived at. No specific formula for reaching this division has yet been developed. A study of the cost of repairs per mile divided between running and classified work does not present a solution, because whenever it is necessary to decrease or increase forces and expenses, the fluctuation is felt directly in the back shop and only indirectly in the roundhouse. It is generally known, of course, that whenever it becomes necessary to curtail expenses or make reductions, it is a simple matter to close the back shops but not possible to make corresponding reductions in roundhouses because certain forces must be maintained in the latter at all times, and under such circumstances even in larger number. For that reason running-repair costs follow a more uniform trend, and the policy of the extent to which engines are given running repairs in roundhouses must be fashioned according to the relation of road time to time allowed for turning, which is largely affected by the units available for service call. Running repairs are not so directly affected by the disposition of revenues as classi-

fied repairs except where the carrier is in a position to enjoy revenues which exceed the expenses to such a degree as to constantly insure earning the net requirements. There is no argument against the great need of having uniform forces and avoiding the closing of shops, because excessive fluctuations in forces cause repair programs and the continuity of work to be disrupted, and in addition destroy discipline. Shop output is, generally speaking, directly affected by fluctuations and expenses, and this seriously affects the frequency of classified repairs.

One way of measuring performance with shop output is to compile the locomotive-miles run since last shopping, setting this up in a cumulative way monthly and comparing it with the miles restored in classified repairs. The miles restored must necessarily be based on the assigned mileage, and the balance between miles run out and restored cannot be accurately judged unless the assigned mileage is practically correct and consistent with actual performance. When the assigned mileage is set too high, then there will be more restoration of mileage reported by shop output than is actually run out; on the other hand, if the assigned mileage is too low, then the restoration is not in keeping with the run-out mileage. The experience of the C. M. & St. P. along this line has developed the fact that the application of the assigned mileage for each type of power, regardless of its use, is not sufficiently specific, and such process, when employed, needs revising by developing an assigned mileage for each type of power and for each division so that the local characteristics as to track, curvature, gradients, service, consequent tire and lateral wear, and boiler repairs can be considered as factors. Theoretically it is possible to group repairs into time cycles, but time is only one of the elements of shopping power, and as the frictional wear is mostly overcome in roundhouses the time element for shopping power resolves itself very largely into cycles based on necessity for heavy boiler repairs.

The factors used by the author's read in the general plan of shopping are assigned mileage, time, and actual physical condition based on customary and frequent inspections. Where there is a low rate or run-out mileage, time enters into the calculation to a greater degree than where mileage is run out rapidly. Physical condition is a vital element to overcome the differences in divisional characteristics or variations in the service rendered according to track, water, and other features. In addition, it can be arranged to set a limit to expenditures for the various types of power according to the class of repairs to be given, any overexpenditure to be reported and explained so that extraordinary repairs may be a matter of record. The regulation of frequency of repairs to locomotive parts is a matter of long-range study and the cycling of repairs cannot be followed specifically in all cases, although it has been the company's general policy to endeavor to follow a class No. 3 repair with a No. 4 or No. 5 and then with another No. 4 or No. 5 followed by a class No. 3, in other words, having two minor repairs between two major repairs; but this depends upon the nature of service performed and the severity as well as the rapidity with which mileage is run out. It cannot at the outset be presumed that we can obtain approximately 50 per cent of the mileage between classified repairs for the first class No. 3 repairs and then 25 per cent for each of the minor repairs, as experience has developed that inasmuch as taking up lateral, tire turnings or changes, etc. constitute a classified repair, tire and lateral wear develop and become due for renewal just as soon after a class No. 3 as after a class No. 4 or No. 5 repair; so that it is well to contemplate a distribution of the mileage and make it equal for each class of repairs, whether a No. 3, No. 4, or No. 5 class, but regulate the cost of each shopping accordingly.

A Study of Enginehouse Operation

A study of shop and roundhouse facilities cannot be summarized in terms of specific units so as to outline the direct effect upon policy and the results thereof. It involves the number of roundhouses per mile of track, the frequency of turning locomotives or the miles run between turnings, etc. As a matter of interest, it may be stated that during the time in which the change in policy referred to was taking place, studies were made of enginehouse operation not only as to repairs made but as to the cost of turning power, frequency of turning, etc. with results shown in the table immediately following.

	Transportation Expense (Not Maintenance)		
	1922	1923	1924
Average turnings per month....	53,572	59,784	54,911
Average cost per month.....	$430,492	$384,969	$331,830
Average cost per engine turned.	8.30	6.44	6.04
Average cost per engine-mile, cents.....	10.25	8.35	7.68
Average miles run between turnings.....	78	77	78

No comparison can be made with other carriers in this respect because the methods of counting engines turned, the accuracy of distributing charges, the nature of roundhouse facilities, etc. vary too greatly. The above figures are merely given to show that the trend in other expenses affected by locomotives was downward the same way as indicated in Fig. 1. It is very apparent that the frequency of turning power decreases with the increase in average distance between roundhouses, and that the average miles per engine turned will increase with the spread in distance between roundhouses. This naturally involves the general study of utilization of power.

A statement of the actual hours of service per engine per day reflects the intensity of use and efficiency in turning, all of which depends largely upon the condition of power, the amount owned, and the character of maintenance. We have not been able to observe any adverse effects on the turning of engines because of decrease in frequency of back-shop repairs; it might have been assumed that so low a frequency as was developed in the change of policy would throw too much of a burden upon roundhouses for intermediate repairs and increase the hours of detention. The cost per mile of running repairs incurred in roundhouses is greater than the cost per mile of classified repairs made in the back shops, the former running rather uniformly with the number of engines turned and the latter fluctuating more in relation to increase or decrease in operating expenses because of regulating them according to revenues.

The formulation of a specific policy of back-shop attention to power, therefore, must consider a wide scope of performance, embracing the amount of property owned in relation to the demand and use thereof, the type and size of power, shop and roundhouse facilities and their relation to each other, road conditions, rapidity with which mileage is run out and restored, the ability to maintain a minimum but uniform force in back shops throughout the entire year, the ability in addition to increase the rate of repairs in the low-peak-loading months so as to have a larger supply available for service in high-peak months, the range of variation between high- and low-peak months, etc. Where back-shop and roundhouse facilities are modernized and properly regulated by means of machine tools, power plants, handling devices such as cranes, hoists, tractors, manufacturing devices and an adequate store stock, it should be possible to determine closely the final balance between classified and running repairs with its relation to the cost of performance expressed in various units of measure, some of which have been outlined above.

Bearing of Utilization of Power on Shopping Policy

The utilization of power requires careful and detailed study because any variation must of necessity have a marked bearing upon shopping policy. It has been found when comparing the performance of a greater number of carriers than used in plotting Fig. 2 that the tendency to run out locomotive-miles rapidly increases somewhat with the increase in size of power, and, as before stated, the rate at which mileage is run out is a determining factor in the proper frequency of classified repairs. There is a great variation in the mileage performance, and this reflects either good or poor power assignment and use, or a high or low density of traffic. Where the percentage of locomotives required for business is large in relation to the total ownership, where the monthly mileage is high, and where the hours of service per day are above the average of eight, this reflects a small reserve for detention in and awaiting shops, and the back-shop efficiency is then a more vital factor and the time consumed in making repairs is a greater element than where opposite conditions prevail. The average number of days out of service for the item of in and awaiting shop is not a matter of uniform record and therefore is not always available, but it is well

to make mention here of the importance of having for this purpose a detailed knowledge of the number of days locomotives are out of service. It is possible to arrive at the average days of detention in the past so as to regulate the future by the use of the following formula:

Let A = average number of locomotives in and awaiting shop per month
B = total locomotives owned
C = total days in the year and
D = frequency of shopping.

Then

$$\frac{A}{B} \times C = \text{Average number of days detention per locomotive per year}$$

and

$$\frac{A}{B} \times C \times D = \text{Number of days detention per shopping.}$$

In cases where the percentage of power in service is low as compared with the total owned it is usually found that the hours of service per day are low or approximately six, which makes it possible to have a large waiting list and to turn locomotives less rapidly through the shops and still have ample protection for service. It would be expected that where the average size of power was small there would be more units out of service than where the average size of power was large, other things being equal, but on the other hand the data supporting the chart indicate that where large power runs out mileage as rapidly as small power it incurs a greater frequency of back-shop repairs, probably due to terminal facilities not having been improved to the same extent as the motive power. With some carriers the shopping detention is serious, while with others it does not create a problem; yet the tendency should be to increase the utilization of power, and increased utilization will depend largely upon its condition and the degree of maintenance. A campaign along the lines of reducing the number of units in active service to a minimum consistent with traffic handled, based on the average miles per locomotive despatched or the average miles between locomotive turnings (enginehouse operation) will necessarily avoid the purchase of new equipment for the purpose of increasing the complement, because when longer runs are installed and fewer locomotives are used for a given service, this naturally builds up a surplus. With a surplus of power the shopping problem is less acute. Where the gross ton-miles per train-hour indicate a slow movement in a territory where traffic is dense, trains should not be delayed because of short runs made by locomotives and frequent delays due to changing power. Movement in this case requires acceleration, and to overcome this trouble it is necessary not only to increase the length of locomotive runs but to eliminate intermediate terminals and classify trains so that the local service will be confined to the fewest possible trains, permitting a greater number to proceed without such interruption. Intensive service requires a revision of the method of repairs, and in some cases calls for a higher standard of repairs than where more locomotives are used in the same service. The objective should be to get more locomotive-miles per month out of fewer active locomotives and more hours of service per day out of each locomotive; then other factors will naturally increase the gross ton-miles per train-hour.

Turning to the problem of the time element applied to locomotive output, where orders are issued to shops for locomotives of a certain character to be made ready for service on short notice, the time factor, as regulating the date of delivery, is very often a matter of supreme importance. A study of this question very soon brings to light an intricate problem with which supervisors and others in authority have to grapple. One of the outstanding factors is that of the machine-tool and material-handling equipment, with which is identified the means of producing work rapidly and to the best advantage. Many of the latest machine tools, cranes, tractors, etc. are conspicuous for the facility with which they can be operated, the controls being conveniently placed, thus saving time in setting up and subsequently handling the machines. Another equally vital point is that of the organization of the work, which must, if time is to be saved, be planned on a definite and progressive system. All these measures are applicable to old as well as to the most modern new shops; however, they are likely to lose much of their value unless the workmen themselves coöperate in the avoidance of time wastage. Slackness in commencing work when first arriving at the shops or in resuming after an interval may result in an aggregate representing a very considerable loss of time, and make it difficult or impossible to get the engines completed to schedule. Similarly, stopping unnecessarily soon each day before the whistle blows, if indulged in on anything like a wide scale, must necessarily reduce the effective value of the working day. Piece-work and unit-output-measure systems are designed to make such action on the part of the workmen unprofitable to them, but even where these are in force it is often found impossible to correct the loss. It is therefore only through the strict coöperation of every one concerned, combined with proper shop systems and the use of tools and facilities fully adapted to their purpose, that rapidity of production can be assured.

Conclusion

One point of serious practical importance remains, namely, that the designated mechanical officer should place before his executive a practical and sound analysis of the requirements for the upkeep of motive power, shops, power plants, and tool equipment, and recommendations for expansion or rehabilitation to save against existing unit expense known to be out of keeping with the possibilities for best achievement. It is also desirable to view the problem from the standpoint of (1) Performance, (2) Cost, and (3) Progress.

In making submissions for proposed expenditures they may be grouped under items or savings as dealing with:

1 Fuel
2 Labor
3 Materials
4 Delay to Train Movements
5 Accident Prevention or Personal Injury.

Once we have grasped these fundamental facts, we can promptly get rid of not a few popular fallacies already referred to. It is regrettable and not a little surprising that in fixing ordinary running expense and upkeep the budget allowance to be approved by any administration should fail to be based upon the requirements as made necessary because of traffic or operating conditions and complying with a general policy formulated to properly care for conditions in the most effective and economical manner, and not altered to fluctuate with current temporary drops in traffic, which are often seasonal. Where there is an increase or decrease in business handled during a long period it is necessary to modify the assignment of forces employed in such a way as will permit of increasing forces economically, that is, gradually, if materials and facilities are in readiness to absorb the advantage of greater forces to be employed, and to decrease them without permitting the property to depreciate or build up deferred maintenance. Such changes in the budget should never be made without the most careful consideration of all phases of the problem, based on considerations of a broad policy. For instance, during the course of five or ten years the traffic on a given property may warrant certain expenditures for maintenance of locomotives, shops, power plants, tool equipment, and new locomotives; this expenditure should be made constantly each and every year. The policy of trying to maintain an even or favorable allocated net earning capacity each month, regardless of the business handled, in order to save against financial fluctuations as to credit or stock issues, acts to cause a considerable influence to make administration difficult, particularly during low seasonal movements. An accumulative allocated net trend, with a full knowledge of balances between losses and gains, should permit of a more even flow of maintenance work. Unless this is done a stable policy cannot readily be worked out or maximum economy obtained with a minimum outlay for facilities and for labor. What should be arrived at is a reasonable maintenance standard for the property as a whole. The basis should be gaged from a consideration of the general earning capacity and also upon the kind and class of traffic handled. With this part correctly fixed, slight fluctuations in business should not materially alter the yearly progress as applied each month with the view toward stability of employment and proper discipline and administration of the work. In a large sense the motive-power man is only as successful as his management will let him be. This is one

of the reasons why so many able men have left the railroad service for other and more productive fields. Every motive-power man of wide experience knows what a lack of executive support or full coöperation means. The best policy on earth avails little if it does not have support from the top of the organization down. Too many of our executives judge the mechanical man by locomotive-miles produced without any direct reference to work done by the locomotives, which is a vital factor. It is for this reason that data was presented here to indicate not only mileage performance, but a composite factor of mileage and size or capacity.

One other point in conclusion: It has frequently proved to be the case that, regardless of all of the devices and methods employed to increase the efficiency of power, the personnel and organization employed are the most important in this respect. There is a great difference of opinion as to whether or not a locomotive is due for shopping. Judgment in this respect varies, but the basis depends largely upon training and the policy adopted, whether expressed or implied. The psychology of high or low frequency varies. The human factor in shopping policy is as vital as the material factor.

Analysis of Power-Plant Performance Based on the Second Law of Thermodynamics

Details of a Step-by-Step Method of Analyzing Power-Plant Performance That Shows the Losses of Available Energy Occurring in Each Stage of the Process

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IT IS customary to analyze power-plant performance by preparing a heat balance based on the first law of thermodynamics to show the distribution of the heat of combustion of the fuel. The object of operating a power plant, however, is not to distribute heat but to convert heat into mechanical work. An analysis based upon the second law of thermodynamics is therefore much more enlightening than the usual first-law heat balance, because such an analysis shows the lost opportunity for converting heat into mechanical work due to the imperfections in each stage of the process.

Before presenting such an analysis, some remarks will be made upon the second law of thermodynamics. These remarks are believed to be in order since engineers apparently have such a hazy idea of the meaning of the second law. The first law can be stated in very simple words, such as:

> Heat and mechanical work are different forms of energy, and when one is converted into the other, the ratio is 778 ft-lb. to 1 B.t.u.

The same brevity has been attempted in stating the second law, with the result that this law has generally been a jingle of words rather than a working tool. In order to present a definite conception of the second law which will enable it to be used as the basis for an analysis of power-plant performance, some very elementary principles will first be stated.

To do mechanical work it is necessary to exert a force through a distance, because work is so defined. The addition of heat to a solid body or to a fluid generally expands the substance, even against considerable resistance. The mechanical work thus performed is equivalent to a greater or less proportion of the heat added. With isothermal expansion of air under moderate pressures, for example, practically 100 per cent of the heat added is converted into mechanical work. The idea that such a thing is impossible is one widespread misconception of the second law. The second law of thermodynamics, however, does not apply to this case, but only to cases where the same medium must be used over and over again.

Under this limitation it is impossible on this earth to convert into mechanical work 100 per cent of the heat supplied for the reason that some heat must be rejected by the working substance to contract it in order that it may again be expanded in using it the second time. To expand the working substance there must be a "source of heat" at a higher temperature than the working substance; and to contract the working substance there must be a "source of cold" at a lower temperature. By bringing the working substance alternately into contact with the "source of heat" and the "source of cold," mechanical work may be performed equivalent to the difference between the heat supplied from the source of heat and that rejected to the source of cold.

As shown by Carnot, there is a certain maximum ratio of the heat converted into mechanical work to that supplied from the source of heat, which ratio is the efficiency of a perfect engine. This ratio is a function of the upper and lower temperatures only, and is independent of the nature of the working substance used in the perfect engine. The Carnot cycle shows theoretically how this perfect engine must operate. The Stirling cycle shows another method of attaining the maximum efficiency, but a working substance with certain specific-heat relations is required.

From textbooks on thermodynamics, the following mathematical expressions may be obtained for the maximum possible conversion of heat into mechanical work and the corresponding minimum rejection of heat to the source of cold with the Carnot cycle. Calling these quantities the "available energy" and "unavailable energy," respectively, we have

$$\text{Available energy, } dW = \frac{T - T_0}{T} dQ = (T - T_0)dS \quad [1]$$

$$\text{Unavailable energy, } dQ_0 = \frac{T_0}{T} dQ = T_0 dS \quad [2]$$

where T = absolute temperature of the source of heat
T_0 = absolute temperature of the source of cold
dQ = heat supplied at temperature T to the working substance in a perfect engine
dQ_0 = heat rejected at temperature T_0 by the working substance in a perfect engine
dW = heat converted into mechanical work by a perfect engine, and
dS = dQ/T, by definition the change in entropy of the material source of heat.

These mathematical relations express the second law of thermodynamics for which the following statement is proposed:

> When a medium is used to convert heat into mechanical work by operating in a closed cycle between an upper absolute temperature T and a lower absolute temperature T_0, only a portion of the heat supplied at the upper temperature can be converted into mechanical work when the lower temperature is above absolute zero; and the relation between the heat supplied at the upper temperature dQ, the maximum quantity available for conversion into mechanical work dW, and the minimum quantity rejected at the lower temperature dQ_0, is given by
>
> $$\frac{dQ}{T} = \frac{dW}{T - T_0} = \frac{dQ_0}{T_0} \quad [3]$$

This relation also applies to the reverse operation, but we are not at present concerned with refrigerating machines.

Based on this statement of the second law of thermodynamics, it is possible to analyze the performance of a power plant step by step and tabulate the losses of available energy occurring in each stage of the process. In explaining this analysis to classes in thermodynamics, the greatest difficulty encountered has been to get the students to understand that the perfect engine of Carnot or Stirling is applied simply as a measuring rod at each step of the process, none of the fluids in the power plant analyzed being the medium used in the perfect engine. The underlying conceptions for this analysis are: (*a*) A perfect engine is assumed to be operated by heat supplied from each of the actual fluids in turn, furnace gases, steam, etc. at each step in the process; (*b*) The temperature of heat supply will vary according to the change in temperature which would be experienced by the fluid in question giving up its heat to the perfect engine; (*c*) The temperature of exhaust of the perfect engine will be constant and equal to that of the atmosphere or of the water available for condensing purposes.

In applying relations [1] and [2] to determine the available energy and the unavailable energy at any step in the process, the calculations are very simple when steam is the source of heat to the perfect engine because the entropies of steam are tabulated. In this case, by integration of [2] we have

$$\text{Unavailable energy, } Q_0 = T_0(S_1 - S_2) \quad [4]$$

$$\text{Available energy, } W = Q - Q_0 \quad [5]$$

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where S_1 and S_2 are the entropies of the steam at the beginning and end, respectively, of the withdrawal of heat which is supplied to the perfect engine.

For the furnace gases, of which the entropies are not known, Formula [2] may be integrated by using the relation

$$dQ = (a + bT)dT \quad [6]$$

where a and b are the specific-heat coefficients. Relation [6] may be integrated to obtain the heat supplied by the furnace gases in cooling from T_1 to T_2, namely,

$$\text{Energy supplied, } Q = a(T_1 - T_2) + \frac{b}{2}(T_1^2 - T_2^2) \quad [7]$$

$$= \left[a + \frac{b}{2}(T_1 + T_2)\right](T_1 - T_2) \quad [7a]$$

Integrating [2] with the aid of [6], we have

$$\text{Unavailable energy, } Q_0 = aT_0 \log_e \frac{T_1}{T_2} + bT_0(T_1 - T_2) \quad [8]$$

$$\text{Available energy, } W = Q - Q_0 \quad [9]$$

When the specific heat may be assumed constant with a sufficient degree of accuracy, Formulas [7] and [9] reduce to

$$\text{Energy supplied, } Q = a(T_1 - T_2) \quad [10]$$

$$\text{Unavailable energy, } Q_0 = aT_0 \log_e \frac{T_1}{T_2} \quad [11]$$

$$\text{Available energy, } W = Q - Q_0 \quad [12]$$

The calculations for unavailable energy are simpler than for available energy; and as the change in unavailable energy for any stage of the process must equal the change in available energy, the former is generally calculated in preference to the latter.

As an example of the application of the second law of thermodynamics enunciated above, the performance of a locomotive will be analyzed, the following data being taken from Pa. R.R. Bulletin 28, for test No. 3925 of Mikado type locomotive, Pa. Class L1s:

Heating value of coal	14,044 B.t.u. per lb. of dry coal
Temperature in firebox	2490 deg. fahr.
Temperature in smokebox	494 deg. fahr.
Temperature of feedwater	70 deg. fahr.
Temperature of superheated steam in branch pipe	555 deg. fahr.
Temperature in exhaust pipe	263.1 deg. fahr.
Atmospheric pressure	14.2 lb. per sq. in.
Steam pressure in branch pipe	193.7 lb. gage, say, 208 lb. per sq. in. abs.
Pressure in exhaust passage	8.2 lb. gage, or 22.4 lb. per sq. in. abs.
Dry coal fired per sq. ft. of grate surface	86.6 lb. per hr.
Steam to engines per lb. of dry coal fired	7.03 lb.
Steam per indicated horsepower	18.2 lb. per hr.

The calculations for the ordinary heat balance based on the first law will first be made:

1297.4 B.t.u. per lb. total heat of superheated steam from steam tables

38.1 B.t.u. per lb. heat in feedwater from steam tables

1297.4 − 38.1 = 1,259.3 B.t.u. to produce one lb. of steam

1259.3 × 7.03 = 8853 B.t.u. transmitted to the steam per lb. of dry coal.

For a temperature of 2490 deg. fahr. in the fuel bed and a heating surface temperature of, say, 390 deg. fahr., we have

$$1600\left[\left(\frac{460 + 2490}{1000}\right)^4 - \left(\frac{(460 + 390}{1000}\right)^4\right] =$$

1600 (75.74 − 0.52) = 120,350 B.t.u. per hr. per sq. ft. of grate surface radiated from the fuel bed to the heating surface

$\frac{120{,}350}{86.6}$ = 1390 B.t.u. per lb. of dry coal reaches the heating surface by radiation

8853 − 1390 = 7463 B.t.u. per lb. of dry coal reaches the heating surface by convection.

Assume the specific heat of the products of combustion to be given by 0.24 + 0.00002 T, where T is the absolute temperature in degrees fahrenheit. The mean specific heat between T_1 and T_2 is then given by 0.24 + 0.00001 (T_1 + T_2) B.t.u. per lb., or according to Formula [7a],

[0.24 + 0.00001 (460 + 2490 + 460 + 494)](2490 − 494) = 0.279 × 1996 = 556.9 B.t.u. per lb. of products of combustion given up to heating surface

$\frac{7463}{556.9}$ = 13.40 lb. of products of combustion per lb. of dry coal.

[0.24 + 0.00001(460 + 494 + 460 + 70)](494 − 70) = 0.225 × 424 = 108.1 B.t.u. in stack gases per lb. of gases

108.1 × 13.40 = 1449 B.t.u. in stack gases per lb. of dry coal

8853 + 1449 = 10,302 B.t.u. per lb. of dry coal produced by combustion

14,044 − 10,302 = 3742 B.t.u. per lb. of dry coal lost by unburnt fuel, incomplete combustion, etc.

$\frac{18.2}{7.03}$ = 2.59 lb. of dry coal per hr. burned per indicated horsepower

$\frac{2546}{2.59}$ = 983 B.t.u. converted into mechanical work per lb. of dry coal

8853 − 983 = 7870 B.t.u. in exhaust steam per lb. of dry coal

$\frac{7870}{7.03}$ = 1119 B.t.u. per lb. of exhaust steam above 70 deg. fahr.

1119 + 38 = 1157 B.t.u. per lb. total heat of exhaust steam

202.2 + x × 957.8 = 1157, whence x = 0.997 = dryness fraction of exhaust steam.

NOTE: The temperature in the exhaust pipe was 263.1 deg. fahr. by measurement, thus indicating 29 deg. of superheat. It is therefore probable that the superheat in the steam initially was greater than measured. To be consistent, however, the exhaust steam will be assumed to have the quality calculated.

FIRST-LAW BALANCE

	B.t.u.	Per cent
Heat lost by unburnt coal, etc.	3,742	26.7
Heat lost in stack gases	1,449	10.3
Heat converted into work	983	7.0
Heat rejected in exhaust steam	7,870	56.0
Heating value of dry coal	14,044	100.0

Calculations for the second-law balance will now be made of available energy and unavailable energy at each step of the process in order to determine the loss in available energy, or gain in unavailable energy, during each stage. We shall assume the lower temperature to be that of the feedwater, 70 deg. fahr. (530 deg. abs.)

During the first stage of the process, namely, the combustion of the fuel, the 3742 B.t.u. per lb. of dry coal not produced by reason of unburnt coal, incomplete combustion, etc. is evidently unavailable for conversion into mechanical work.

Of the 10,302 B.t.u. per lb. of dry coal resulting from combustion, 1390 B.t.u. are radiated from the fuel bed at the constant temperature of 2490 deg. fahr. From Formula [2],

$1390 \times \frac{460 + 70}{460 + 2490}$ = 1390 × 0.1797 = 250 B.t.u. per lb. of dry coal unavailable portion of radiant heat.

1390 − 250 = 1140 B.t.u. per lb. of dry coal available portion of radiant heat.

The remainder of the 10,302 B.t.u., namely, 8912 B.t.u. per lb. of dry coal, reaches the heating surfaces by convection of the furnace gases. That is, this heat leaves the furnace in 13.40 lb. of products of combustion at 2490 deg. fahr. (2950 deg. abs.). Substituting in Formula [8] under the assumption that these gases are cooled to 70 deg. fahr. by imparting their heat to operate a perfect engine, we have

$$530\left[0.24 \log_e \frac{2950}{530} + 0.00002\,(2950 - 530)\right] =$$

530 × 0.4604 = 244.0 B.t.u. unavailable energy per lb. of furnace gases

13.40 × 244.0 = 3270 B.t.u. unavailable energy in furnace gases per lb. of dry coal

8912 − 3270 = 5642 B.t.u. per lb. of dry coal available in firebox gases for transformation into mechanical work by a perfect heat engine.

These products of combustion escape to the smokebox at a tem-

perature of 494 deg. fahr. (954 deg. abs.) and have a sensible heat above 70 deg. fahr. of 1449 B.t.u. per lb. of dry coal. Substituting in Formula [8],

$$530\left[0.24 \log_e \frac{954}{530} + 0.00002(494 - 70)\right] = 530 \times 0.1496$$

= 79.29 B.t.u. unavailable per lb. of smokebox gases

13.40×79.29 = 1062 B.t.u. per lb. of dry coal unavailable energy in smokebox gases

$1449 - 1062$ = 387 B.t.u. per lb. of dry coal available energy in smokebox gases, but lost with these gases passing out the stack.

Of the 10,302 B.t.u. per lb. of dry coal resulting from combustion, therefore,

$1140 + 5642$ = 6782 B.t.u. per lb. of dry coal are available for conversion into mechanical work by a perfect engine.

But 387 B.t.u. of this available energy are lost with the escape of the products of combustion out of the stack. Hence, of the heat transferred to the steam,

$6782 - 387$ = 6395 B.t.u. per lb. of dry coal were available for conversion into mechanical work by a perfect engine before the transmission of heat through the heating surface.

To find the availability of the 8853 B.t.u. per lb. of dry coal transmitted through the heating surface after its transmission, we obtain from steam tables:

1.6486 entropy per lb. of superheated steam and

0.0746 entropy per lb. of water at 70 deg. fahr.

Substituting in Formula [4],

$530(1.6486 - 0.0746)$ = 834.2 B.t.u. unavailable per lb. of steam

7.03×834.2 = 5864 B.t.u. per lb. of dry coal unavailable energy in the superheated steam

$8853 - 5864$ = 2989 B.t.u. per lb. of dry coal are available for conversion into mechanical work by a perfect engine after transmission through the heating surface

$6395 - 2989$ = 3406 B.t.u. per lb. of dry coal loss of available energy due to heat transfer in the boiler.

Now, for the exhaust steam, we have from the steam tables corresponding to the quality previously determined,

$1.7293 - 0.003 \times 1.3809 = 1.7252$ entropy per lb.

Substituting in Formula [4],

$530(1.7252 - 0.0746)$ = 874.8 B.t.u. unavailable per lb. of steam.

7.03×874.8 = 6150 B.t.u. per lb. of dry coal unavailable energy in exhaust steam.

Since the exhaust steam contains 7870 B.t.u. per lb. of dry coal (above water at 70 deg. fahr.) according to previous calculations, we have

$7870 - 6150$ = 1720 B.t.u. per lb. of dry coal available for conversion into mechanical work by a perfect engine, but carried out by the exhaust steam.

Since 2989 B.t.u. per lb. of dry coal were available in the steam entering the engine and 983 B.t.u. per lb. of dry coal are equivalent to the work actually done, we have

$2989 - 983 - 1720$ = 286 B.t.u. per lb. of dry coal loss of available energy due to imperfections in the engine cylinders.

It may be noted that if the engine cylinders had been less imperfect in their operation, the available energy lost in the exhaust steam would have been somewhat less. The possibility of improvement in the engine cylinders is therefore somewhat greater than the figure 286 would indicate.

Summing up the losses of available energy, we obtain

SECOND-LAW BALANCE

	B.t.u.	Per cent
Unavailable due to unburnt fuel, etc.	3,742	26.6
Unavailable part of radiant energy	250	1.8
Unavailable energy in firebox gases	3,270	23.3
Available energy lost in smokebox gases	387	2.8
Available energy lost by heat transfer	3,406	24.2
Heat transformed into work	983	7.0
Available energy lost by imperfections in cylinders	286	2.0
Available energy lost in exhaust	1,720	12.3
Heating value of dry coal	14,044	100.0

Comparing the first-law balance with the second-law balance, we find some items appearing in the latter which do not occur in the former, while other items are greatly altered in their relative proportions. Thus, one of the largest losses appearing in the second-law balance is that due to heat transfer in the boiler, amounting to nearly one-quarter of the heating value of the fuel. This is the loss that is now being successfully attacked and reduced by the use of higher steam pressures and other fluids than water, such as mercury.

The loss in the exhaust steam appears reduced from over one-half of the heating value of the fuel in the first-law balance to less than one-eighth in the second-law balance, which is its correct relative importance. In an analysis of a condensing plant the loss in the exhaust is a still lower portion of the heating value of the fuel, thus indicating the gain due to the use of condensers.

In calculating the second-law losses during combustion, various assumptions might be made in order to prorate these losses among unburnt fuel, incomplete combustion, excess air, etc. and in certain cases it will be desirable to attempt such a division. The order in which the calculations are made, however, will affect the prorating. In many cases the simple expedient adopted in these calculations will suffice.

In presenting the second-law analysis for the first time, a simple case has been chosen for illustration, namely, a locomotive. No great difficulties, however, will be encountered in applying this analysis to more complicated power systems. While somewhat more complicated calculations are required for the second-law balance than for the usual first-law balance, it is believed that the facts revealed thereby will more than justify its extended use.

In closing, the author wishes to acknowledge his indebtedness for the general idea of preparing a second-law balance to Dr. R. C. Tolman, of the California Institute of Technology.

A Microscopic Study of Pulverized Coal

Results Showing That Screen Tests for Fineness May be Misleading in Making Comparisons of Pulverizing Mills

BY L. V. ANDREWS,[1] WORCESTER, MASS.

THE usual expression of the fineness of pulverized coal is given as the percentages of the sample passing through standard 100-mesh or 200-mesh screens. It is commonly assumed that pulverized coal of which 95 per cent will pass through a 100-mesh screen and 85 per cent through a 200 mesh screen, is suitable for all practical purposes, although considerable deviation is allowed from these percentages in current practice.

This method of specifying pulverized coal is not necessarily indicative of the quality of such coal with respect to fineness; i.e., one sample of pulverized coal testing 85 per cent through a 200-mesh screen may be entirely different from another sample testing to the same percentage through a 200-mesh screen, when the fines distribution below 200-mesh are considered.

As an illustration, mix two samples of pulverized coal. For sample No. 1 let the mixture have the following proportions by weight:

All through 60 mesh and on 100 mesh	5 per cent
All through 100 mesh and on 200 mesh	10 per cent
All through 200 mesh and on 250 mesh	85 per cent

and for sample No. 2 make the following mixture:

All through 60 mesh and on 100 mesh	5 per cent
All through 100 mesh and on 200 mesh	10 per cent
All through 1000 mesh and on 1200 mesh	85 per cent

It must be admitted that sample No. 2 would be much better for burning, from a combustion standpoint, than sample No. 1, for in all cases the finer coal will ignite more readily and burn more completely than coarser coal, assuming that the other factors relating to combustion are equal.

If the customary screen tests were run on these samples, the same results would be shown for both: namely, 95 per cent through a 100-mesh screen and 85 per cent through a 200-mesh screen.

It is obvious, then, that merely testing by the two standard screens will not indicate the quality of coal with respect to fineness unless there is a uniform graduation, or rather a similar gradation of the size of particles from the coarsest to finest in the samples being tested.

Types of Pulverizers

It is not readily conceivable that the two dozen or more pulverizers on the market in the United States today will give the same proportionate graduation in fineness, especially when the numerous distinct types of machines are considered with reference to grinding action and the further segregation due to different methods by which pulverized material is removed from the machine.

Considering pulverizing actions only, there are four distinct types of pulverizers in common use, a fifth which has been tried out quite thoroughly in at least two instances, and possibly others of which no information has been secured. These are classified as follows:

Contact Mills. In this class are listed all the mills in which the coal is ground in a thin sheet or ribbon between two elements which have a rolling action with respect to each other, and which consist of a circular bull ring as one element, within which are revolving balls or rollers comprising the second element. The two elements are forced together by the action of centrifugal force or powerful springs, thus crushing any material which is introduced between them.

Tube and Ball Mills. This type employs as grinding members either tubes, rods, or balls, or combinations of these, forming one element, contained in a horizontal revolving cylinder which comprises the second element. Pulverization is accomplished by the tumbling action of these tubes, rods, or balls when the cylinder is set in motion, and takes place between the members comprising the first element as well as between these and the shell of the revolving cylinder.

Impact Mills. In this class are all the new types of unit pulverizers so rapidly gaining in favor which employ as primary grinding elements high-speed paddles, pegs, or hammers which shatter the coal particles by striking them at high speed or by hurling the particles violently against each other or against stationary liners, corrugations, or pegs, which may be considered as secondary elements.

Attrition Mills. In this class are machines employing a rubbing action between the grinding surfaces. This type is not in general use for powdered-coal preparation.

Roll Mills, No Contact. In this type of mill pulverizing is done by passing a ribbon of coal between rolls which crush it between them in a manner similar to that used for grinding wheat to make flour. This type of mill has not proven generally successful for fine coal grinding.

Microscopic Examination of Samples

Inasmuch as power must be expended for grinding in a pulverizer of any character, it is obvious that less power will be consumed if the material be removed just as soon as it attains the specified fineness instead of remaining in the pulverizer until reaching a greater fineness. This leads to considering the necessity for determining accurately the fineness of product before passing judgment on the merits of a pulverizer based on power consumption per unit of material ground. Inasmuch as there is a reasonable possibility that the standard screen tests are not accurate enough, it should be determined whether or not there is a uniform gradation of fines among the samples from pulverizers of which there is more or less accurate information.

The best way actually to visualize any difference which may be present is to examine each sample under the microscope, making a note of the proportionate quantity of extreme fines to that of the coarsest in the sample being examined.

Photomicrographs of several samples are shown below and a careful examination of them will verify the conclusions reached, but they do not show up as distinctly as the original slides, due to the impossibility of photographing and printing them with the same sharpness as revealed to the naked eye.

Preparation of Samples for the Microscope

The following precautions should be taken in the preparation of similar studies if results of a reliable character are to be obtained:

a Extreme care must be taken in the making of the microscopic slides to secure uniform preparation conditions so that the results may be comparable.

b A magnification must be used sufficient to show the 200-mesh particles distinctly.

c Diffused, transmitted light is best to bring out as much contrast as possible and to prevent refraction of the light from the coal particles, which gives an erroneous impression of both the size and shape.

d Provision must be made for some means whereby the size of the particles may be measured or whereby a comparison of sizes may be made in different pictures.

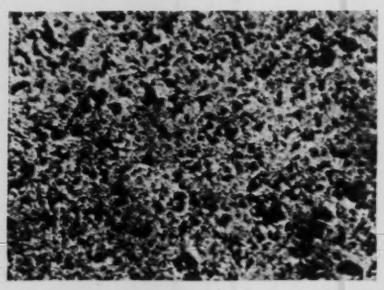
e Some liquid must be used to hold the particles in suspension and prevent the fines from accumulating in masses which resemble large particles.

f A careful selection of a field of view must be made in each case so that all the photographs may show a uniform density of particles distribution, thereby making the photographs visually comparable.

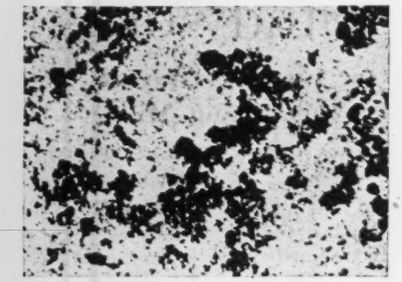
[1] Development Dept. of Riley Stoker Corp.

Contributed by the Fuels Division for presentation at the Spring Meeting, Milwaukee, Wis., May 18 to 21, 1925, of The American Society of Mechanical Engineers. All papers are subject to revision.

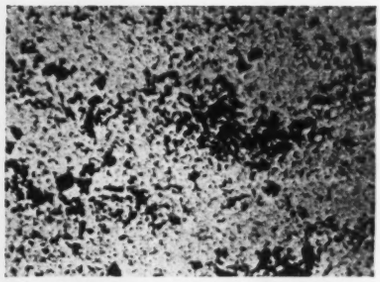
Be sure to bring this copy with you to the Spring Meeting



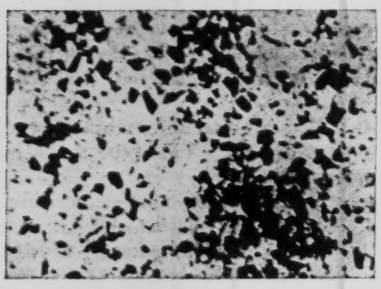
No. 1 Through 100 mesh, 98 per cent; through 200 mesh, 83.6 per cent; moisture, (approx.) 1.5 per cent.



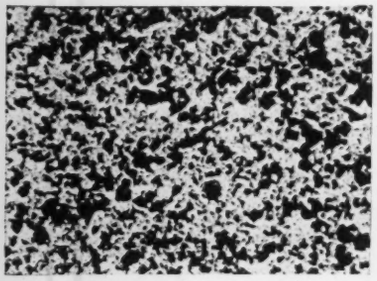
No. 2 Through 100 mesh, 95 per cent; through 200 mesh, 73 per cent; moisture, (approx.) 1.25 per cent.



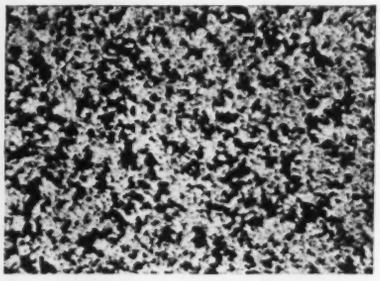
No. 3 (Previously screened to 100 mesh.) Through 100 mesh, 100 per cent; through 200 mesh, 75.4 per cent; moisture, (approx.) 6 per cent.



No. 4 Through 100 mesh, 62.4 per cent; through 200 mesh, 34.4 per cent; moisture, not obtained.

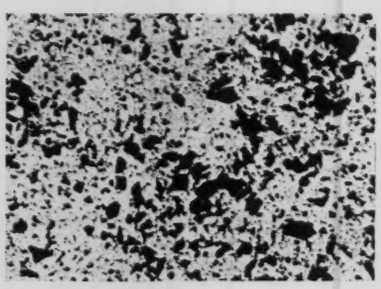


No. 5 Through 100 mesh, 75.2 per cent; through 200 mesh, 52.2 per cent; moisture, (approx.) 0.43 per cent.

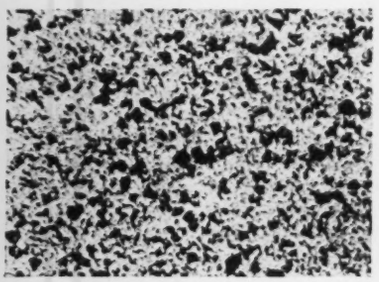


No. 6 Through 100 mesh, 93 per cent; through 200 mesh, 76 per cent; moisture, (approx.) 0.92 per cent.

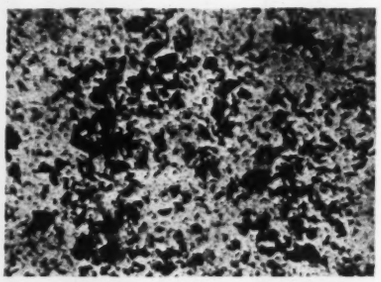
PHOTOMICROGRAPHS OF SAMPLES GROUND IN CONTACT MILLS (MAGNIFICATION × 50)



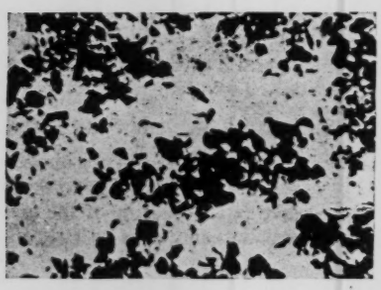
No. 7 Through 100 mesh, 98.6 per cent; through 200 mesh, 91.2 per cent; moisture entering pulverizer, 2.23 per cent; moisture leaving pulverizer, 0.7 per cent.



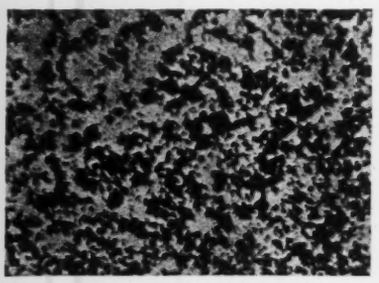
No. 8 Through 100 mesh, 98 per cent; through 200 mesh, 85 per cent; moisture, not given.



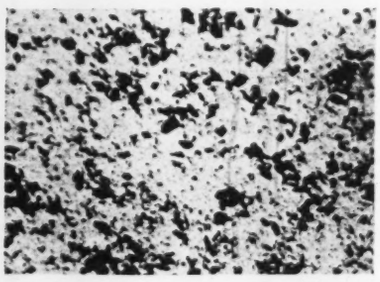
No. 9 Through 100 mesh, 94 per cent; through 200 mesh, 49.4 per cent; moisture, (approx.) 5.5 per cent.



No. 10 Through 100 mesh, 100 per cent; through 200 mesh 47 per cent; moisture, (approx.) 3 per cent.



No. 11 Through 100 mesh, 93.56 per cent; through 200 mesh, 61.3 per cent; moisture, not given.



No. 12 (Not supplied as pulverized coal.) Through 100 mesh, 30 per cent; through 200 mesh, 17.4 per cent; moisture, 6 to 8 per cent.

PHOTOMICROGRAPHS OF SAMPLES GROUND IN IMPACT MILLS (MAGNIFICATION × 50)

It was found that Canada balsam separated the particles of coal well enough for all practical purposes and assisted greatly in the slide preparation because of its adhesive qualities. The method of slide preparation was as follows:

A drop of balsam was placed in the center of the slide and the cover glass was lowered upon this, thus spreading the drop of balsam evenly, after which the cover glass was slipped off the slide and laid aside until again needed. A frame 3 in. square covered with 200-mesh screen silk was then placed over the slide, being supported so that the screen lay approximately 1 in. above the glass. A small amount of coal could then be worked over the screen and an even film would be deposited in the balsam on the slide. The cover glass was then held with the balsam-coated side up and a small drop of balsam was added to the center, after which the glass was turned over and deposited on the slide. The spreading of this last drop of balsam excluded the air, thus preventing bubbles. The cover glass was then slipped around over the slide by a slight rotary movement which segregated the particles of coal to the desired density of field.

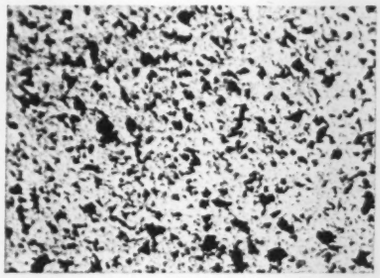
In making the photographs care was taken to select fields of view having as nearly as possible the same coarse-particle distribution, and three sets of prints were made from the negatives so that a

set of prints could be had having, as nearly as possible, a print shade common to all.

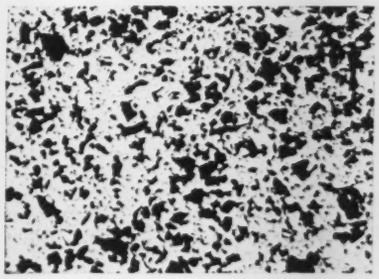
The accompanying photomicrographs are classified according to type of grinding action as previously described and are given a prefix number which denotes the sample number to distinguish it from samples produced by other mills of the same type. These photomicrographs were taken at a magnification of 50 diameters with transmitted light, and show only 200-mesh and finer material. They were prepared by the Norton Company Research Laboratory from slides furnished to them by the author.

STUDY OF THE PHOTOMICROGRAPHS

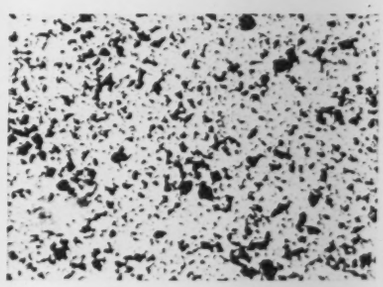
Screen tests are given for all samples except that from the roll mill, no-contact type. The only sample at hand from this mill had been formerly screened to 100 mesh, but was too small to admit of accurate screen testing. The samples obtained from a few other mills were also too small to admit of accurate screen testing, but the manufacturers obligingly furnished the figures as listed with the samples.



No. 13 Through 100 mesh, 88.8 per cent; through 200 mesh, 66.8 per cent; moisture, (approx.) 0.50 per cent.

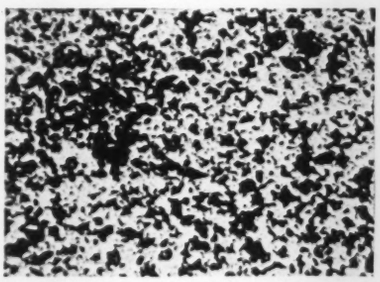


No. 14 Through 100 mesh, 65 per cent; through 200 mesh, 40 per cent; moisture, not given.

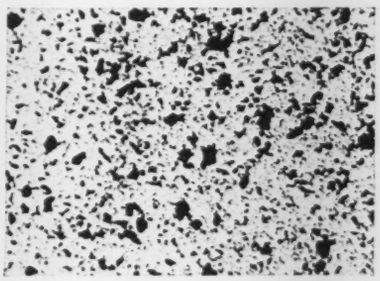


No. 15 Through 100 mesh, 83.4 per cent; through 200 mesh, 62.5 per cent; moisture, not given.

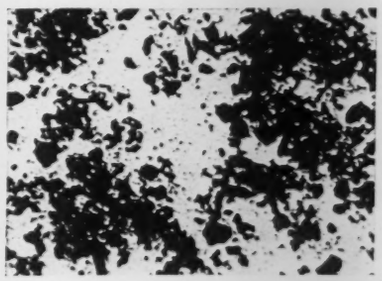
PHOTOMICROGRAPHS OF SAMPLES GROUND IN TUBE AND BALL MILLS (MAGNIFICATION × 50)



No. 16 Impact Mill. Through 100 mesh, 100 per cent; through 200 mesh, 66.6 per cent; moisture, not given.



No. 17 Attrition Mill. Through 100 mesh, 100 per cent; through 200 mesh, 89.6 per cent; moisture, not given.



No. 18 Roll Mill. No Contact. Moisture, not given.

PHOTOMICROGRAPHS OF SAMPLES GROUND IN OTHER TYPES OF MILLS (MAGNIFICATION × 50)

(These samples had been screened to 100 mesh previously)

An examination of these pictures shows distinctly that there is a wide range of difference in fineness below 200 mesh in the samples examined. Particular attention is called to sample No. 4, impact mill, and to sample No. 1, attrition mill. In sample No. 4, impact mill, scarcely any extreme fines are observable, while in sample No. 1, attrition mill, the major portion consists of extremely fine particles. However, this effect is shown to a greater or less extent by the standard screen tests. Both of the samples show 100 per cent through 100 mesh, but the impact mill shows only 47 per cent through 200 mesh while the attrition mill shows 89.6 per cent through 200 mesh.

An examination of the photographs of sample No. 1, contact mill, and sample No. 2, impact mill, shows almost identical fines distribution, and these samples are comparable by the screen tests, both showing 98 per cent through 100 mesh and practically the same through 200 mesh; the contact mill showing 83.6 per cent and the impact mill 85 per cent.

These two comparisons would indicate that a screen test was reliable. However, sample No. 1, tube and ball mill, is practically the same in appearance, although its screen test shows only 66.8 per cent through 200 mesh. This sample shows a great deal more fines than does sample No. 2, contact mill, a screen test of which would indicate a much better grade of product, as it gives 95 per cent through 100 and 73 per cent through 200 mesh.

By going a step further an attempt may be made to reconcile the photographs with the results indicated by the screen tests. Assuming that all the coal samples had been screened through 100 mesh, then the percentage through 200 mesh should indicate the effectiveness of grinding with respect to fines below 200 mesh, and it would be expected that the lower the percentage through 200 mesh, the coarser would be field shown in the photographs.

The following table shows the percentage of 100-mesh material of each sample which would go through 200 mesh:

Place	Sample No.	Per cent through 200 mesh
1	1—Impact Mill	92.5
2	1—Attrition Mill	89.6
3	2—Impact Mill	86.8
4	1—Contact Mill	85.5
5	6—Contact Mill	81.7
6	2—Contact Mill	76.8
7	3—Contact Mill	75.4
8	1—Tube and Ball Mill	75.2
9	2B—Tube and Ball Mill	74.8
10	5—Contact Mill	69.3
11	7—Impact Mill	66.6
12	5—Impact Mill	65.5
13	2A—Tube and Ball Mill	61.5
14	6—Impact Mill	58.0
15	4—Contact Mill	55.2
16	3—Impact Mill	52.5
17	4—Impact Mill	47.0
18	Not considered	....

By examination of the photomicrographs it is found that this classification does not indicate the degree of fineness below 200 mesh by a wide margin, for sample No. 1, tube and ball mill, in eighth place, appears to be much better than sample No. 1, impact mill, in the first place, and sample No. 4, contact mill, in the fifteenth place, appears to be just as good.

Nor by examination of these photomicrographs can any one type of pulverizer be shown to be better than any other, although the performance of individual machines can be compared to some extent, provided there is not too much difference in the way in which different coals break down during the process of pulverization. This point, together with considerations with regard to moisture content at the time of pulverizing, was not taken into account in the foregoing, and the appearance of the photographs submitted

need not, for these reasons, be taken as a final proof of the merits of the machines which made the samples.

SUGGESTED METHOD OF ESTIMATING FINES

It is entirely probable that if the percentages of a sample were determined by passing it through a number of screens and a curve plotted using this information, the characteristics of this curve might give some indication of the fines distribution below 200 mesh, which is about as fine as it is practicable to go by sieving. This phase of the subject was not studied in connection with the data herein presented, but the method is advocated by one manufacturer of high-grade screening equipment.

METHOD OF SAMPLING

The method of sampling determines to quite an extent the accuracy of the samples collected. This is especially true of the unit type of machines. In a test on one unit pulverizer, a variation of 8 per cent in the 200-mesh material was experienced with a corresponding variation of over 5 per cent in the 100-mesh material; this variation being found in taking samples across the discharge pipe. The finest material was at the surface and the coarsest at the center of the discharge passage. This condition has been observed by other investigators, and the use of a sampling pipe extending entirely across the discharge passage has been recommended.

The material used for precipitating or collecting the dust will also play a big part in the number of fines collected. The best material for filtering seems to be finely woven cloth, although a filter made of fine steel wool is being used with very good results.

CONCLUSIONS

However, this study does show conclusively that the standard 100-mesh and 200-mesh percentage method of testing pulverized coal is at fault, in that it is not complete enough to show the actual pulverizing work done and that it may actually be misleading in a comparison of two samples. The microscope should be consulted, or a more elaborate screen test run, in all cases where it is desired to know exactly what quality of pulverized coal is being delivered by the machine.

Aluminum and Its Light Alloys

Data on the Mechanical Properties of Alloys for Sand, Permanent-Mold, and Die Castings, Wrought Aluminum, High-Strength Alloys and Forgings Therefrom, Etc.

By ROBERT L. STREETER[1] and P. V. FARAGHER,[2] PITTSBURGH, PA.

ALUMINUM has advanced from the position of a laboratory curiosity to that of an important commercial metal in a comparatively short period of time. The properties of the metal upon which this development is based are primarily its lightness or low specific gravity, high thermal and electrical conductivity, pleasing appearance, resistance to atmospheric corrosion and to certain types of chemical attack, the non-toxicity of its compounds, and the ease with which it can be wrought. The commercially pure metal is quite soft in the cast or annealed condition and has only moderate strength when wrought cold.

The desire to improve the mechanical properties of the metal and at the same time retain its desirable properties has resulted in the development of a large number of light aluminum alloys. The increase in strength and hardness which is obtained in the alloys is gained at a sacrifice of some of the ductility and workability of the metal. In most cases the resistance to corrosion is lessened, although some of the alloys are at least the equal of the commercial grades of pure metal in this respect. Most of the alloys contain 90 per cent or more of aluminum; the specific gravities vary from 2.65 to 2.90 as compared with 2.70 for the commercially pure metal.

It is the purpose of this paper to make available to the engineer data on the mechanical properties of aluminum and its light alloys. The recent literature contains a large amount of information on the developments in this field. The data which have been published are, however, to a great extent the results obtained in laboratory investigations and do not represent minimum values which may be used by the designer for commercial materials.

FIG. 1 ALUMINUM PIPES 31 IN. IN DIAMETER USED FOR TRANSMISSION OF GASES IN A NITRIC ACID WORKS

The data presented in this paper are minimum properties obtained from numerous tests of commercial material and may be used by the engineer with the assurance that such materials are available on the market.

The term "aluminum," as commonly used, denotes not only the commercially pure metal but also the alloys in which aluminum is the principal constituent. Aluminum is available in a great variety of forms. It can be rolled, forged, extruded, drawn, spun, and cast. The list of commercial wrought forms includes plate, sheet, foil, tubing, bar, rod, wire, moldings, structural shapes, rivets, forgings, automatic-screw-machine products, and castings produced in sand, in permanent molds, and by the die-casting process.

ALUMINUM CASTING ALLOYS

Although the mechanical properties and casting characteristics of commercially pure aluminum are not such as to recommend it for general casting purposes, it is used to some extent where its chemical and electrical properties are preferable to those of the common casting alloys.

It is possible by the addition of relatively small amounts of other elements to commercially pure aluminum to produce alloys which possess very satisfactory mechanical properties and good foundry characteristics, and at the same time retain in a large measure the desirable properties of the commercially pure metal. The most commonly used alloying elements or "hardeners" are copper, silicon, zinc, and manganese, and to a lesser degree, nickel and magnesium. These hardeners differ among themselves in the percentages which are required to produce a given increase in the tensile strength or hardness and also in the effects on the other properties which accompany the change in strength of the alloy. These facts are best seen by reference to Table 1, which gives the mechanical properties and approximate compositions of the most commonly used casting alloys of aluminum.

Of the large number of alloys which have been proposed, only a few have come into general use. The standardization on a relatively small number of alloys is the natural result of several factors. The necessity of simplifying the problem of the utilization of secondary metal, the desire to avoid complex alloys with their attendant difficulties of composition control, and the dictates of economy in the choice of alloying elements exercise the greatest influence in limiting the number of alloys.

The largest tonnage of castings produced from aluminum alloys is poured in sand molds. The most commonly used alloys are marketed in ingot form for remelting. They are manufactured in large lots under careful chemical and pyrometric control, and by their use the foundry may avoid the difficulties which are encountered in the preparation of alloys on a small scale.

The field for each of the methods of casting is rather sharply defined. The sand-casting process is applicable to the most varied types of work both as to size and shapes which can be produced. The accuracy of dimensions is not so great as in the permanent-mold or the die-casting processes, and in general more allowance must be made for machining and finishing operations. The surface finish is inferior to that obtained in metal molds.

Permanent-mold castings are used where a superior product is required but where a forging cannot be used, either because of the form of the part or because of cost considerations. The strength of a casting produced from a given alloy in a permanent mold is about twenty per cent greater than that obtained from a sand casting, and the hardness and ductility are correspondingly greater. The dimensions may be controlled more accurately than in a sand casting, and either a machined or polished surface will show greater freedom from defects. By the use of permanent-mold castings it is often possible to effect appreciable saving in weight due to the ability to design to closer limits. Because of the cost of producing the molds, this type of casting is available only for quantity production.

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The die-casting process is adapted to the production of castings in which extreme accuracy, uniformity, and superior finish are essential. In this process very thin walls may be cast, with the consequent saving of weight in the finished part. Holes may be cast to very close tolerances and the dimensions can be controlled so closely as to reduce machining operations to a minimum. Because of the excellent surface, polishing and finishing operations are greatly simplified. In this case also the die cost is such that the die-casting process is suitable only for castings which are produced in large quantities.

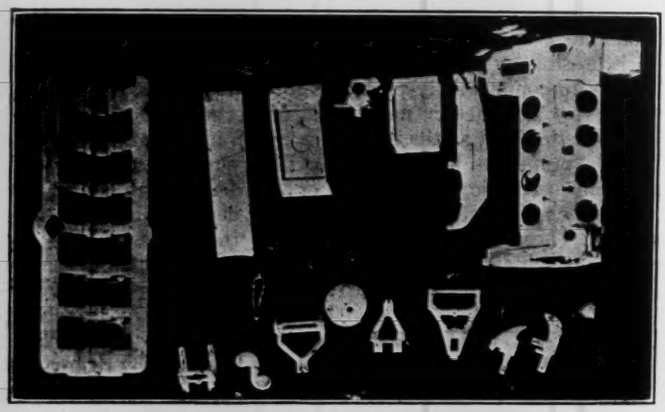


FIG. 2 MISCELLANEOUS ASSORTMENT OF SAND CASTINGS

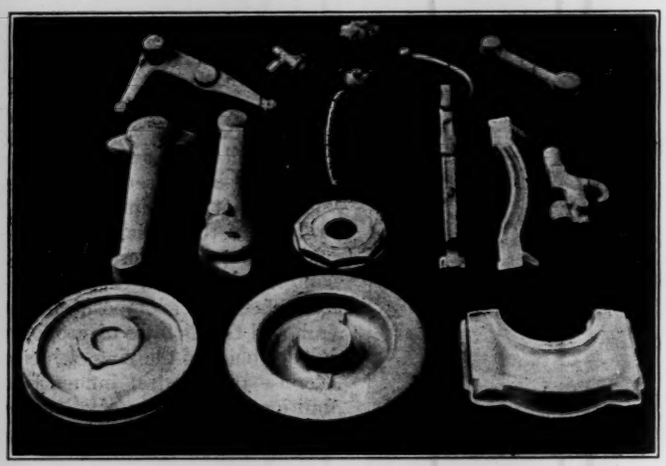


FIG. 3 FORGINGS AND PERMANENT-MOLD CASTINGS

In comparing the accuracy with which these products can be produced the following comparison is of interest. For die castings tolerances are discussed in thousandths of an inch, for permanent-mold castings, in thirty-seconds and sixty-fourths, while for sand castings tolerances are considered in eighths and sixteenths.

TABLE 1 ALUMINUM CASTING ALLOYS

(Properties obtained from unmachined sand-cast test specimens)

Alloy No.	Approx. composition	Ultimate tensile strength, lb. per sq. in.	Elongation per cent in 2 in.	Approximate yield point, lb. per sq. in.	Brinell hardness number
100	99% aluminum..	12,000–14,000	15–25	4,000	25
12 (S.A.E. No. 30)	8% copper.....	18,000–23,000	1–3	10,000	65
112 (S.A.E. No. 33)	7.5 copper, 1.5 zinc, 1.2 iron	19,000–24,000	1–2.5	11,000	65
109	12% copper.....	19,000–26,000	0–1.5	15,000	70
43 (S.A.E. No. 35)	5% silicon.....	17,000–21,000	3–7	7,000	40
45	10% silicon.....	19,000–23,000	1–3	9,000	50
47[1]	13% silicon..... (Modified)	25,000–30,000	5–10	11,000	60
106	2% manganese..	16,000–20,000	3.5–6.5	6,000	40
195[1]	4% copper..... (Heat treated)	28,000–35,000	5.5–11	18,000	70
196[1]	5% copper..... (Heat treated)	36,000–45,000	0–2.5	27,000	115
145[1]	10% zinc, 2.5% copper, 1.2% iron	25,500–34,000	3–6	12,000	65

[1] The modification process by means of which the properties specified for No. 47 alloy are realized, the production of castings 195 and 196 in the heat-treated state, and alloy No. 145 are covered by patents or patent applications owned by the Aluminum Company of America.

SAND CASTINGS

Table 1 lists the alloys which are most commonly used for the production of sand castings in the foundries of the Aluminum Company of America, together with the approximate chemical compositions and the mechanical properties which are obtained. The test specimens are poured in sand molds without chills or other means of artificial cooling and are tested without machining.

The values representing the lower limits of the ranges for tensile strength and elongation are regularly guaranteed; the average values are, in general, midway between the upper and the lower limits. The results which are obtained from test specimens machined from castings vary considerably with the nature of the casting and with the size and shape of the section from which the sample is taken. Sand castings which show 80 per cent of the tensile strength of the unmachined cast test specimen are considered indicative of very good foundry practice.

While it is true that more accurate measurements can be obtained from test specimens which are cast oversize and machined accurately to dimensions, the difference between the results which are obtained with such specimens and those obtained from unmachined bars are no greater than the normal variations between individual casts of a given alloy. In view of this fact and of the fact that the test specimen does not represent the strength of the casting but is a means of controlling the quality of the alloy, the added expense and the delay incurred by the use of the machined test specimen are not warranted in routine inspection.

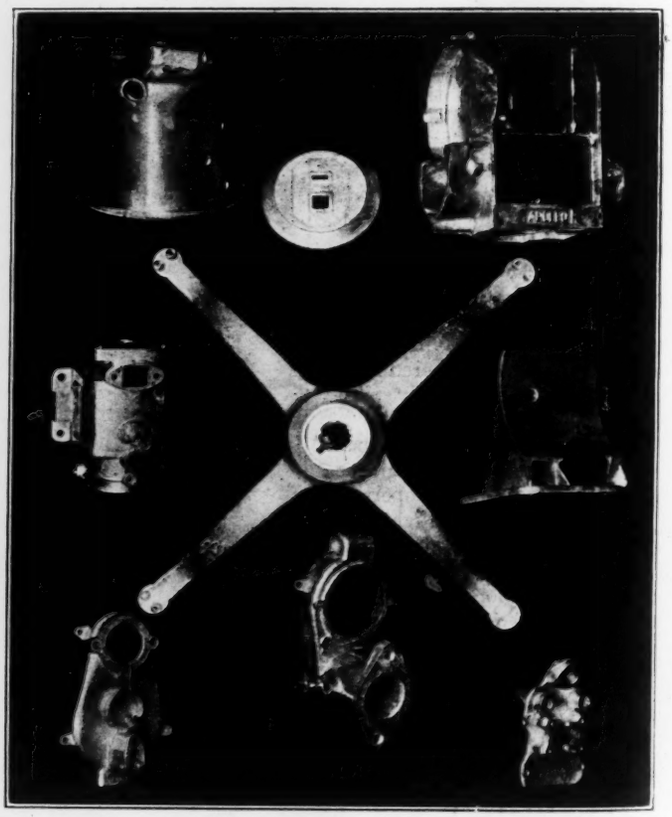


FIG. 4 SMALL DIE CASTINGS

There is a considerable lack of agreement among engineers as to the proper definition of the yield point of nonferrous metals and also as to the best means of measuring it. The values given in Table 1 for the yield point consider this property to be the stress under which the elongation in the gage length of the test specimen is equal to one-half of one per cent of its initial length. This property is not regularly measured in routine inspection and the values given in the table are to be considered as approximate, and not as guaranteed minimum values. The measurement of Brinell hardness is subject to considerable vari-

ation, and the values for this property are also approximate average values.

Each of these alloys has its advantages and its disadvantages, and there is a field in which each excels. The commercially pure metal has the lowest strength and yield point and in addition is difficult to handle in the foundry, but its use is imperative in certain chemical and electrical equipment because of its characteristic properties. Alloys Nos. 12 and 112 are the most widely used of all the alloys and their tonnage is far in excess of all the others for general casting purposes. They are easily handled in the foundry and their extensive use in the automotive industry is proof of their satisfactory properties. No. 112 machines somewhat better than No. 12 and is stronger, but has slightly less ductility. For parts which must be leakproof under pressure, alloy No. 109 may be used, although this advantage is gained at a sacrifice of the toughness and resistance to shock which are shown by the alloys containing the lower percentage of copper.

The aluminum-silicon alloys are quite fluid at temperatures almost down to the freezing point, and they have a low solidification shrinkage. This combination of properties makes it possible to cast intricate shapes having both heavy and thin sections without the excessive use of chills and risers. The castings are dense and leakproof. Silicon has a lower specific gravity than aluminum and its alloys with aluminum are therefore somewhat lighter than commercial aluminum itself. This factor is significant in aircraft-engine construction where even small differences in weight are important. These alloys are perhaps the most resistant of all the casting alloys to salt-water corrosion, which fact makes them especially suited to marine construction. In remelting, somewhat greater care must be used since they show a greater tendency to

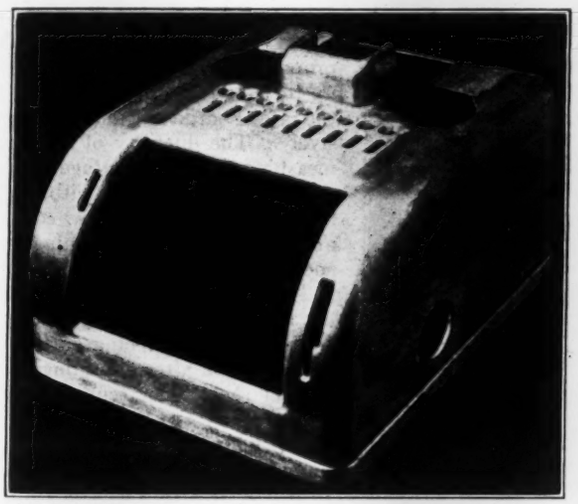


FIG. 5 DIE-CAST ADDING-MACHINE FRAME, WEIGHT 3.38 LB.

absorb iron, which element has a harmful effect on the mechanical properties. It will also be noted that the yield points are lower in proportion to the ultimate tensile strength than in the other alloys, but their elongations are higher. These alloys are more difficult to machine than the other casting alloys.

The properties which are given for No. 47 alloy are obtained only by special modification treatments of the molten alloy according to processes which are covered by patents. Castings made from the unmodified alloy show coarse crystalline fractures and inferior mechanical properties, while castings from the modified alloy show extremely fine silky fractures.

Alloy No. 106 is used almost exclusively for small parts such as pipe fittings where the shrinkage can be easily taken care of. Such fittings are used extensively with wrought aluminum-manganese alloy (3S) pipe and tubing in order to reduce the tendency toward electrolytic corrosion. The alloy is quite resistant to salt-water corrosion.

The properties of Nos. 195 and 196 alloys are developed only after proper heat treatment according to processes covered by patents and patent applications. These alloys show remarkably high strengths and yield points, and the elongation is also very high in No. 195 alloy. These alloys age spontaneously on standing; in this process the strength and particularly the yield point increase and the elongation decreases somewhat. These alloys will naturally be chosen where the mechanical property requirements are sufficient to warrant the added expense of heat treatment.

Castings from No. 145 alloy have good strength and ductility, and are quite resistant to shock. While its properties are not equal to those of the heat-treated alloys, the fact that it does not require heat treatment will frequently cause it to be chosen for those purposes where the properties are adequate. This alloy is also subject to spontaneous aging and shows an increase in strength with some loss of ductility on standing. In common with other aluminum alloys containing relatively high percentages of zinc,

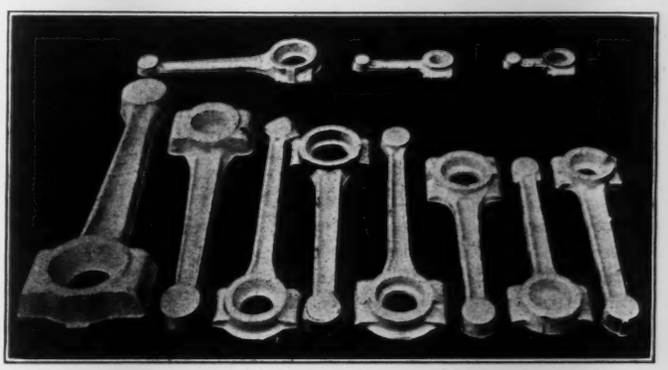


FIG. 6 FORGED CONNECTING RODS

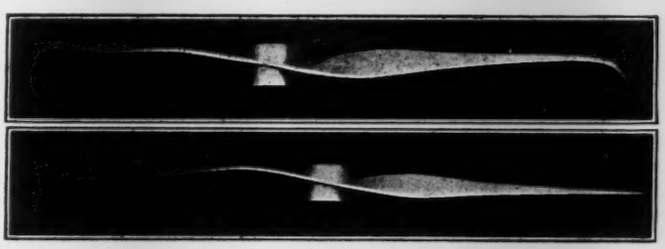


FIG. 7 ALUMINUM-ALLOY AIRPLANE PROPELLER DAMAGED BY IMPACT ON WATER (ABOVE) AND AFTER REPAIRS WERE MADE (BELOW)

it is not adapted for use at high temperatures since it loses its strength rather rapidly at elevated temperatures.

PERMANENT-MOLD CASTINGS

Some of the alloys which were considered with the sand castings are also used in the permanent-mold process, and in addition there are certain alloys which are intended primarily for use in this process. The art of producing permanent-mold castings is still new and is developing rapidly. Whereas most of the production in the past has been confined to castings in which the average weight would not exceed 3 lb., at the present time several castings are being run on a commercial scale in which the weight varies from 5 lb. to 13 lb. Such heavier castings must of necessity not present too great complexity in design.

In addition to the superior mechanical properties possessed by permanent-mold castings, the alloys have greater resistance to corrosion, and greater susceptibility to heat treatment where these processes are applicable, due to the fine grain and greater density of the metal.

Table 2 lists the more commonly used alloys and the mechanical properties which are obtained when they are cast in permanent molds in the form of the standard half-inch test specimens. In giving values for Brinell hardness it is necessary to point out that this measurement is subject to considerable variation, and the range is of necessity rather wide. The values for tensile strengths represent the ranges which are usually obtained in commercial production; the average value is somewhat higher than the mean of the minimum and maximum strengths which are given. In some cases small test specimens have been machined from castings to determine the variations in strength which may occur in different

sections. This specimen has a parallel section of 0.210 in. in diameter and 0.800 in. in length. The results indicate that in actual castings the strength may fall below the minimum values which are given in Table 2.

DIE CASTINGS

The die-casting process was originally developed for use with tin- and lead-base alloys; later zinc-base alloys were added, and finally the art developed to the point where aluminum alloys could be used. All of these alloys are used today, the alloy chosen for a given casting depending upon the requirements which must be met. Where the properties of lightness, corrosion resistance, pleasing appearance, and higher mechanical properties are desired, one of the aluminum alloys will be chosen.

The Aluminum Die Casting Corporation, located at Garwood, New Jersey, uses three different aluminum alloys under the trade name of "Alumac." The approximate composition and the mechanical properties of these alloys are given in Table 3. The properties are those which are obtained from die-cast test specimens having dimensions which simulate those of actual die castings. Because of the nature of the die-casting process, materially different results would be obtained from a die-cast bar of the form and dimensions of the standard test bar which is used for sand castings. The mechanical properties and the quality of the castings obtained with the aluminum-silicon and the aluminum-silicon-copper alloys are superior to those obtained with the aluminum-copper alloys.

The choice of the alloy to be used depends upon both the nature of the casting and the properties that are required. Because of the individual casting characteristics, the three alloys given in Table 3 cannot be used indiscriminately for the production of all types of die castings.

While light-weight castings are the rule, it is not uncommon to produce complicated die castings weighing as much as 10 lb. Some interesting examples of this class of work are shown in Figs. 4 and 5.

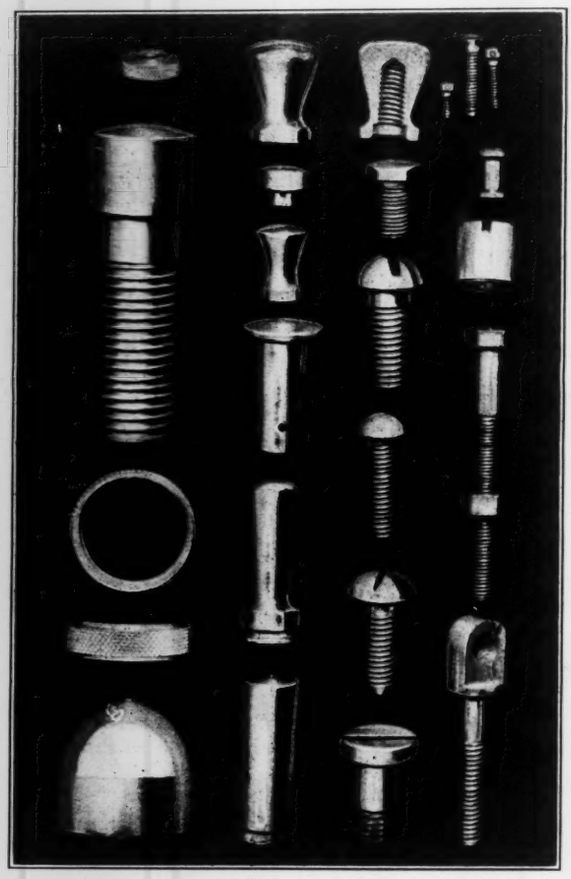


FIG. 8 ASSORTED SCREW-MACHINE PRODUCTS

WROUGHT ALUMINUM

The wrought forms of aluminum are produced from commercially pure aluminum, from an alloy containing approximately one and one-fourth per cent of manganese, and from the recently developed alloys which are susceptible of heat treatment. Some little material is produced from other alloys for special purposes, but the amount is limited and is not to be considered as commercial production.

TABLE 2 PHYSICAL PROPERTIES OF PERMANENT-MOLD-CAST ALLOYS

(Standard 0.505-in. test specimen, cast in permanent mold.)

Alloy No.	Approximate composition, per cent		Tensile strength, lb. per sq. in. Min.	Tensile strength, lb. per sq. in. Max.	Elongation, per cent in 2 in. Min.	Elongation, per cent in 2 in. Max.	Brinell hardness number
43	Silicon	5.0	18,500	24,500	3.0	8.0	40–45
108	Copper Silicon	4.5 5.5	21,000	29,500	1.0	4.5	65–80
45	Silicon	10.0	24,500	29,500	4.5	10.0	45–56
112	Same as sand-cast 112 (as cast)		21,000	29,000	1.5	3.0	70–90
122	Copper Iron Magnesium	10.0 1.2 0.25	22,000	30,000	.0	1.5	85–105
125	Silicon Iron Tin	5.0 1.0 2.0	17,500	22,500	4.3	8.0	40–45
151	Copper Iron Tin	5.5 1.0 1.0	20,500	26,500	3.5	7.5	60–70
152	Copper	10.0	20,500	29,500	1.0	3.0	85–110
195	Copper	5.5	22,000	28,000	3.0	6.0	60–70
	HEAT-TREATED ALLOYS						
	Heat-treat number						
195	4		35,000	39,000	5.0	9.0	70–90
195	10		48,000	54,500	1.0	1.5	110–140
122	2		24,000	30,000	0.5	1.5	90–120
122	7		40,000	48,000	0.5	1.0	125–160
122	12		24,500	32,500	0.5	1.0	125–160
122	14		24,000	30,500	0.5	2.0	95–125
122	15		26,000	32,500	0.5	1.5	115–125

TABLE 3 MECHANICAL PROPERTIES OF DIE-CAST ALLOYS

(Obtained from round, die-cast test specimen, 0.252 in. in diameter.)

Alloy No.	Approximate composition, per cent		Tensile strength, lb. per sq. in.	Elongation, per cent in 2 in.	Brinell hardness number
83	Copper Silicon	2 3	25,000–28,000	3–6	55–65
85	Copper Silicon	4 5	28,000–30,000	2.5–4	60–70
13	Silicon	13	28,000–30,000	1–3	70–80

2S AND 3S

The commercially pure aluminum which is supplied to the trade in the various wrought forms is usually required to show a minimum aluminum content of 99 per cent. This metal is designated as "2S" by the Aluminum Company of America, and this designation is used extensively in the trade. The manganese alloy, designated as "3S," is appreciably stronger than 2S and yet is quite workable in the softer tempers.

In the fully annealed state these metals are quite soft and ductile. When worked cold they are strain-hardened, the tensile strength, yield point, and hardness increasing in proportion to the amount of reduction up to a certain limit, beyond which the rate of hardening increases progressively. The ductility of the metal as measured by the percentage elongation decreases very rapidly with the first amounts of reduction by cold work and at a gradually diminishing rate for successive reductions.

The tempers of 2S and 3S products are based on the properties produced by the strain hardening of the metal by cold work after annealing. In the case of sheet, the tempers may be indicated by the amount of this decrease in thickness measured in gage numbers (the American Wire Gage or Brown & Sharpe Gage is commonly used), since the width remains practically unchanged as the sheet passes through the rolls. For tubing, bar, etc. the actual reduction in cross-sectional area must be calculated to correspond to the reduction which is produced in sheet.

Sheet, tubing, and bar are regularly produced from both 2S and 3S in the annealed temper, in the hard temper, and in three intermediate tempers, designated one-quarter hard, half hard, and three-quarters hard. Sheet in the hard temper is produced by reducing the thickness by cold rolling twelve or more gage numbers after annealing; the same temper is obtained in bar and tubing by a corresponding reduction in cross-sectional area by cold work. While a reduction corresponding to twelve gage numbers in sheet is the minimum for the hard temper, many products have appreciably greater reductions than this as produced according to present commercial practice. This is particularly true of thin sheet, which may be rolled from the annealed slab to the finish gage without intermediate annealing.

The minimum tensile strengths of the intermediate tempers are calculated, however, on the basis of the range between the minimum values for the annealed temper and for the hard temper, regardless of the fact that in certain classes of commercial material the actual difference may be greater. For example, the half-hard

temper has a minimum tensile strength approximately half-way between that of the minimum values for the annealed and for the hard tempers. Similar relations hold for the quarter-hard and three-quarters-hard tempers.

It will be seen from the tables of properties that there is some overlapping of the ranges for the various tempers in both 2S and 3S. This is due to several causes. The slight differences in the composition of different lots of metal, variations in annealing conditions, and the tolerances which are required in fabricating to any given dimensions are all factors in commercial operating practice which influence the final properties of the material.

The elongation is a property which is influenced very largely by the size and shape of the test specimen. This influence is so great that in the case of thin sheet the elongation is of little value in indicating the differences in the workability of the different tempers. The effect of the size of the specimen can be eliminated in the case of bar or other sections from which a round specimen can be machined, by measuring the elongation over a gage length proportional to the diameter of the specimen.

In Tables 4 and 5 are given the approximate ranges for the tensile strengths of the different tempers of 2S and for 3S, together with the minimum or specification values for the elongation of sheet. The elongation of bar and tubing is in most cases appreciably higher than that of sheet because of the effect of the shape of the test piece on the test results. The actual data for these products are not included in the tables but can be obtained from the manufacturer, for the specific sizes and tempers for which the data may be desired.

TABLE 4 PROPERTIES OF 2S ALUMINUM (99 PER CENT MINIMUM ALUMINUM)

Temper	Tensile strength, lb. per sq. in.	Elongation for sheet (minimum), per cent in 2 in. B & S Gage 2–4	5–6	7–9	10–16	17–20	21–24	25–28
Soft	12000–15000	30	30	30	30	25	20	15
¼ Hard	14000–18000		10	10	9	7	6	
½ Hard	16000–20000			7	7	5	4	3
¾ Hard	19000–23000				4	3	2	1
Hard	22000–35000				4	3	2	1

TABLE 5 PROPERTIES OF 3S ALUMINUM (1.25 PER CENT MANGANESE-ALLOY SHEET)

Temper	Tensile strength, lb. per sq. in.	Elongation for sheet (minimum), per cent in 2 in. B & S gage 2–4	5–6	7–9	10–16	17–20	21–24	25–28
Soft	16,000–20,000	25	25	25	20	20	15	10
¼ Hard	19,000–23,000		8	8	7	6	5	
½ Hard	21,000–26,000			6	6	4	3	2
¾ Hard	25,000–28,000				4	3	2	1
Hard	27,000–45,000				4	3	2	1

STRONG ALLOYS

The development of the high-strength aluminum alloys has made aluminum with its properties of lightness, corrosion resistance, and pleasing appearance available as a structural material. Alloys of this type are in commercial production and are available in a large variety of forms: sheet, tubing, bar, rod, wire, forgings, rivets, automatic-screw-machine products, angles and channels both rolled and extruded, and other extruded structural shapes. These alloys are produced in several tempers, the properties varying over a fairly wide range. In the case of these materials the temper depends upon the condition as regards heat treatment.

The Aluminum Company of America produces three alloys of this class: 17S, an alloy of the duralumin type, containing copper, magnesium, and manganese; 25S, containing copper, manganese, and added silicon; and 51S, containing magnesium and added silicon. Each of these alloys has its specific heat-treatment process and its characteristic properties. It should be noted that while these alloys in the cast condition show some improvement on heat treatment, the cast structure must be thoroughly obliterated by working if they are to develop maximum properties in the heat-treatment operation.

These alloys all possess the property of strain hardening when they are worked cold. This strain hardening is removed and the alloy rendered workable by annealing at a suitable temperature. This temperature must be carefully controlled since too low a temperature will fail to soften the metal and too high a temperature will produce effects analogous to those which result from heat treatment though lesser in degree.

The heat treatment consists in heating the alloys to a suitabl temperature and quenching; the actual temperature varies somewhat for the different alloys. Immediately after quenching the alloys are much stronger than in the annealed state, but are distinctly more workable than when in the fully aged condition.

From this point the characteristics of the metals diverge appreciably. The alloy 17S on standing at room temperature undergoes a spontaneous aging, during which process the strength and hardness increase very markedly and the elongation also shows a slight increase. This change proceeds quite rapidly at first then more slowly, and is practically completed in about four days. If it is desired to take advantage of the greater ease of working of the unaged material, the forming must be completed within one or two hours of the time of quenching.

The alloy 51S also undergoes spontaneous aging at ordinary temperatures, but the change is much less pronounced than in the case of 17S. If this alloy is to develop its maximum properties, it must be aged at elevated temperatures. Under these conditions there is a very marked increase in the tensile strength, yield point, and hardness, and an appreciable decrease in the elongation.

The alloy 25S, even on standing for a long time at ordinary temperatures, shows only an insignificant change in properties. If, however, it be heated to a suitable aging temperature, changes in properties occur which are comparable with those which take place spontaneously in 17S.

The effects of the heat-treatment operations may be removed by subsequently heating to the annealing temperature and cooling.

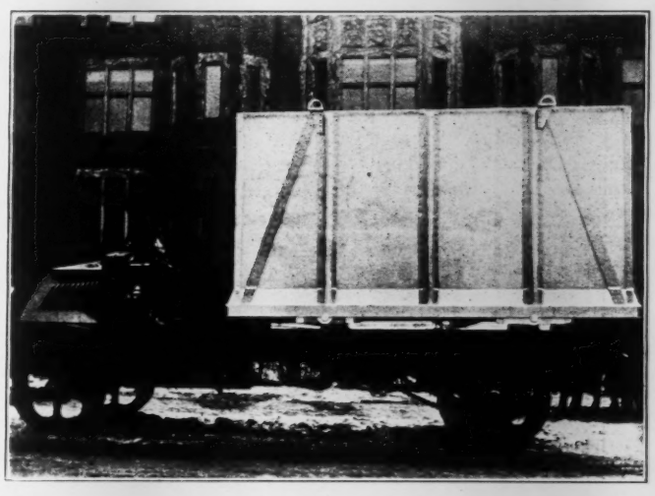


FIG. 9 REMOVABLE TRUCK BODY AND SHIPPING CONTAINER

There appears to be some difference in the properties of this annealed material and that which has not been previously heat-treated in the case of 25S.

The various tempers of these alloys are designated in accordance with the following system: The symbol which designates the temper is added to the symbol for the alloy, the letter O indicates the annealed or soft temper, the letter T the quenched and aged or fully heat-treated temper, and the letter W (used only with 25S and 51S) material which has been quenched but not artificially aged; e.g., 25SO, 17ST, 51SW, etc.

The mechanical properties of 17S and 25S are very similar in corresponding tempers, although there are characteristic differences in their behavior in various forming operations and under different conditions of service. It is interesting to note that the properties in the heat-treated temper are comparable with those of mild steel. The public is familiar with the use of these metals in aircraft construction; the framework of the *Shenandoah* is made of 17S supplied by the Aluminum Company of America, and that of the *Los Angeles*, from duralumin of German manufacture. These metals are also being used in automobile and particularly in autobus construction, as well as in certain parts of railway cars, street cars, and ships. A recent development is in the construction of unit containers for less-than-car-load-lot freight shipments. The advantages of a metal having the strength of mild steel with a weight approximately two-fifths as great do not need to be enumerated.

The alloy 51S in the heat-treated temper has a tensile strength about 10,000 lb. per sq. in. less than that of 17S or of 25S, but

the yield point and hardness are practically identical with those of the stronger alloys. This alloy can be worked with great ease in the softer tempers and the finished articles can be heat-treated to develop maximum properties. Although the elongation of 51S is lower than that of 25S or 17S in the heat-treated temper, in those cases where the material is not subjected to severe forming operations, the high yield point and hardness make this material attractive.

As was stated previously, the properties which are developed in these alloys in the heat-treatment operations depend upon the amount of work which is done upon the cast ingot in reducing it to the desired size. The properties which are given in Tables 6 to 8 will be met by material which in commercial production has received sufficient work to permit the development of maximum properties. According to present commercial practice this will include sheet up to $^1/_8$ in. in thickness, bar and rod up to $^3/_4$ in. in diameter, tubing in all commercial sizes, all moldings, and smaller shapes. In heavier material the tensile strength and yield point may fall below the values given by as much as 5000 lb. per sq. in. The elongation for this heavier material may also fall below the values given by as much as 4 per cent.

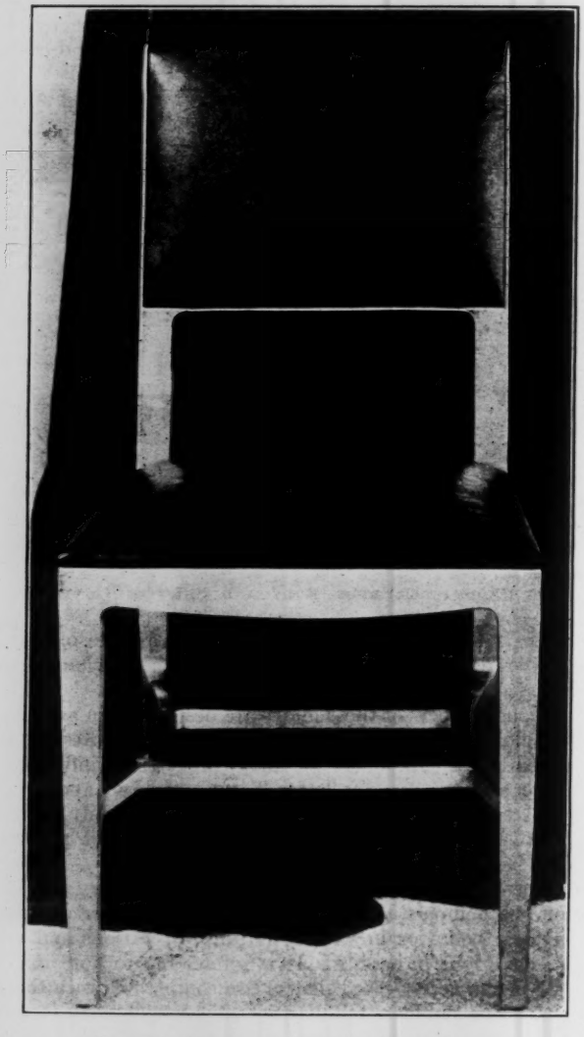


FIG. 10 ALUMINUM STRAIGHT-BACK CHAIR

As was stated when discussing the properties of 2S and 3S products, the measurement of elongation is very much dependent upon the shape of the test specimen. The minimum values for this property are those which are obtained from sheet of intermediate thickness and for bar and rod up to $1^1/_2$ in. in diameter or distance across flats.

In the case of the annealed tempers the material is guaranteed not to exceed the maximum values for tensile strength which are given; the minimum value is not guaranteed.

Shapes which have been produced from these alloys by extrusion and have not been heat-treated subsequently, possess properties intermediate between those of the annealed and the "as quenched" tempers. The metal is extruded at an elevated temperature and the issuing material is cooled in air. This is equivalent to a mild heat treatment, although the temperature of extrusion is not the optimum for heat treatment nor is it subject to close control.

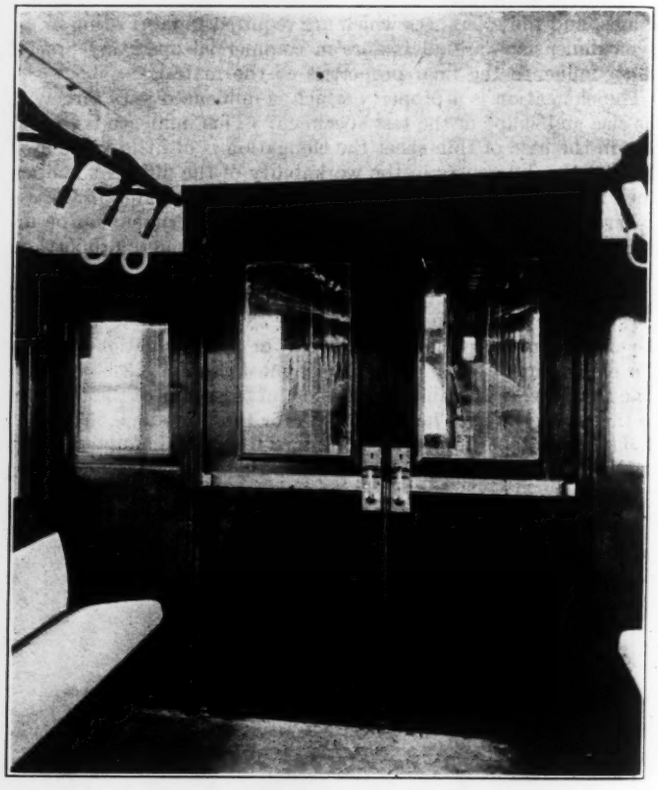


FIG. 11 INTERIOR OF RAILWAY PASSENGER COACH SHOWING DOORS AND INTERIOR CONSTRUCTION OF ALUMINUM

There is considerable variation in this material as extruded, but for certain purposes the properties are adequate.

The alloys Nos. 25S and 51S are covered by patents owned by the Aluminum Company of America.

TABLE 6 MECHANICAL PROPERTIES OF 17S ALUMINUM ALLOY

	17SO	17ST
Tensile strength, lb. per sq. in.	25,000–35,000	55,000–63,000
Yield point, lb. per sq. in.	7,000–10,000	30,000–40,000
Elongation, per cent in 2 in.	12–23	18–25
Brinell hardness (500 kg., 10-mm. ball)	42–50	90–110

TABLE 7 MECHANICAL PROPERTIES OF 25S ALUMINUM ALLOY

	25SO	25SW	25ST
Tensile strength, lb. per sq. in.	25,000–35,000	45,000–53,000	55,000–63,000
Yield point lb. per sq. in.	7,000–10,000	18,000–25,000	30,000–40,000
Elongation, per cent in 2 in.	12–23	15–20	18–25
Brinell hardness (500 kg., 10-mm. ball)	45–50	70–85	90–110

TABLE 8 PROPERTIES OF 51S ALUMINUM ALLOY

	51SO	51SW	51ST
Tensile strength, lb. per sq. in.	14,000–18,000	30,000–40,000	45,000–50,000
Yield point, lb. per sq. in.	4,000–6,000	15,000–20,000	30,000–40,000
Elongation, per cent in 2 in.	15–30	20–30	10–18
Brinell hardness (500 kg., 10-mm. ball)	25–32	55–70	85–100

FORGINGS

The Aluminum Company of America produces strong-alloy forgings in three different grades, these are in accordance with the values shown in Table 9, which represent guaranteed minimum properties.

TABLE 9 PROPERTIES OF STRONG-ALLOY FORGINGS

	Grade		
	1	2	3
Tensile strength, lb. per. sq. in.	55,000	50,000	40,000
Elongation, per cent in 2 in.	16	15	12
Brinell hardness (500 kg. load, 10-mm. ball)	100	90	90

The grade which is supplied depends upon the duty which is to be performed by the forging. Material having properties listed under grade 1 in Table 9 is usually supplied for connecting rods for automobiles, sewing-machine arms, gear blanks, and propellers for aircraft. The high strength combined with lightness make strong aluminum-alloy forgings ideal for high-speed reciprocating parts: vibration and inertia stresses are reduced, with the consequent increase in the life of the machine. The advantages of direct babbitting are also gained by the use of these forgings. Gears made from these alloys can be machined more accurately and more rapidly than is possible with cast iron or steel, and their operation at high speeds is much quieter. The propellers for aircraft forged from these alloys are of about the same weight as wood propellers and have the advantage of longer life. Experience has shown that the metal propellers are not injured by hail or rain, and that in many cases it has been possible to repair damage which was caused by a faulty landing.

For miscellaneous hardware the properties given for grades 2 or 3 in Table 9 are more commonly specified. For this use strong aluminum alloys possess the advantage of ease of finishing and polishing. The finish is permanent, since there is no plated coating to rub off in use. In addition to permanence of finish there is the further advantage of lower cost in comparison with nickel-plated brass.

AUTOMATIC-SCREW-MACHINE PRODUCTS

The Aluminum Screw Machine Products Company manufactures a complete line of automatic-screw-machine products from strong aluminum alloy which it distributes through the Aluminum Company of America. These products have the physical properties which are given in Table 6 for 17ST. They possess the advantages of ease of finishing and permanence of finish which was mentioned under forgings. The cost as compared with nickel-plated brass is very much in favor of the aluminum-alloy products. In many cases aluminum-alloy products are chosen in preference to brass on the basis of cost alone, even where the brass is not to be nickel-plated.

GENERAL

Several reproductions of photographs are included in this paper to show some of the applications which are being made of this very interesting metal. No attempt will be made to list the uses which are being made of aluminum and its alloys. It is interesting to note the fact that many parts can be produced from aluminum and its alloys more cheaply than they can from other metals the price of which per pound is considerably lower. The greater speed of machining and finishing aluminum combined with the fact that the weight of the part from aluminum is approximately one-third that of the same part from brass or iron, are the factors which make this result possible. In other cases the decrease in weight of the entire assembly with the consequent longer life and the saving of power during its operation, are the principal considerations in favor of the use of aluminum.

Aluminum alloys offer very attractive possibilities for decorative castings and objects of art. Statues have been cast from aluminum with very pleasing results. One of the best-known manufacturers of lighting fixtures is producing some very beautiful effects in cast aluminum alloys colored by means of certain processes which are applicable to this metal, and in satin finishes produced either by sand blasting or by dipping. Office furniture has been made from aluminum alloys; some examples are shown in the accompanying illustrations. The cap of the Washington Monument and the finial of the Standard Oil Building in New York City are aluminum-alloy castings.

In contemplating the future of aluminum in the engineering field, one is impressed with the necessity of further and continued research among the strong alloys. Wherever a reduction in weight will result in a saving of power, aluminum or other light alloys will have to be considered in design; and just as sure as the physical properties and cost of manufacture of those alloys become more satisfactory, so will they receive more favorable consideration by engineers.

Test of a Uniflow Engine

Results Obtained with Loads Ranging from One-Quarter to Full Load (400 kw.), with Two Different Steam Pressures, Two Different Back Pressures, Two Different Percentages of Clearance, And with Saturated and Superheated Steam

By GEO. H. BARRUS,[1] BOSTON, MASS.

THIS paper consists of a brief account of a series of tests which the author has recently conducted on a four-cylinder vertical uniflow engine, non-condensing, driving a 400-kw. a.c. Burke generator, direct connected, as shown in Fig. 1, with loads ranging from one-quarter to full load, with two different steam pressures, two different back pressures, two different percentages of clearance, and with saturated and superheated steam.

The tests were conducted for the Great Western Laundry Company, of Chicago, making use of the testing plant of the Ames Iron Works, Oswego, N. Y., in which the engine was designed and built.

The cylinders and heads are steam-jacketed. The cylinder jackets extend around a belt at both top and bottom of the cylinders with openings leading to the jacket spaces in each head. The steam on its way to the steam chest passes through the jackets, and the condensate, if any, is free to drop into the bottom heads, whence it is discharged through a mechanical trap. Except at very small loads the sweep of the steam keeps the condensate in motion, and the trap rarely discharges either water or steam.

The admission valves are double-beat poppets, lifted vertically by a horizontal camshaft. This shaft is moved laterally by a horizontal centrifugal spring-resisted governor, which varies the cut-off according to the lateral position of the cams.

The cylinders are arranged in two pairs, with cranks 90 deg. apart. The two corresponding cranks of either pair are 180 deg. apart. Two cylinderfuls of steam are thus withdrawn from the source of supply at each quarter of a revolution. The total volume of these piston displacements is 0.71 cu. ft., that of the entire jacket spaces and steam chests is 8.2 cu. ft., and that of the throttle valve and piping from the cylinder flange to the stop valve on the steam drum, 2.0 cu. ft. These volumes are purposely mentioned to permit the comparison of the amount of steam withdrawn from the storage spaces at each double steam admission with the total space. The amount withdrawn each time is thus only about one-twelfth of the jacket volume. In this connection it was noticeable that the fluctuations of steam pressure at the throttle valve were extremely small; indeed, the cock on the steam gage at the throttle was kept wide open, and the gage pointer vibrated not more than its own width. The steam-pipe diagrams taken at the throttle valve revealed the same substantial absence of fluctuations, being practically straight lines. These results are obviously brought about by the influence of the multiple cylinders and the storage spaces of the jackets. The practical absence of pressure variation in the steam main contributes not only to steam economy but to structural advantages as well, for it makes the pipe itself secure with a minimum amount of anchorage; further, it enables the size of the pipe to be reduced to the smallest permissible diameter—in this case 5-in. extra heavy. The velocity of the steam in the pipe at the greatest load (15,214 lb. per hr., average) is estimated at 108 ft. per sec. (6480 ft. per min.).

The moving parts of the engine are shut in by a casing, and no adjustment from the outside can be made, while in operation, except to vary the speed by tightening or loosening the governor spring. This construction admits of the efficient use of a pressure oiling system for the lubrication of the entire engine, no oil cups or grease cups being required.

The engine as equipped for testing purposes is shown in Fig. 1. Its dimensions are given in Table 1. The apparatus for measuring the steam consumption consists of a surface condenser of ample capacity, placed below the level of the engine and discharging by gravity into a pair of steel-plate weighing tanks, which are alternately filled and emptied.

In conducting the tests the methods recommended by the A.S.M.E. were substantially followed. The tests were carried out in a continuous series for each set of conditions, starting with the light load, then changing to the next load, and so on, or vice versa. Each test was of sufficient duration to collect a half-dozen or more tankfuls at a substantially constant rate, the intervals between different loads being long enough to fully establish the changed conditions. Under each load the current from the generator was absorbed by a water rheostat, and the load was maintained constantly at the desired point by hand regulation at the switchboard or rheostat terminals. The loads selected (exclusive of direct-current exciter, using from 3 to 5 kw.) were 100, 200, 300, and 400 kw.

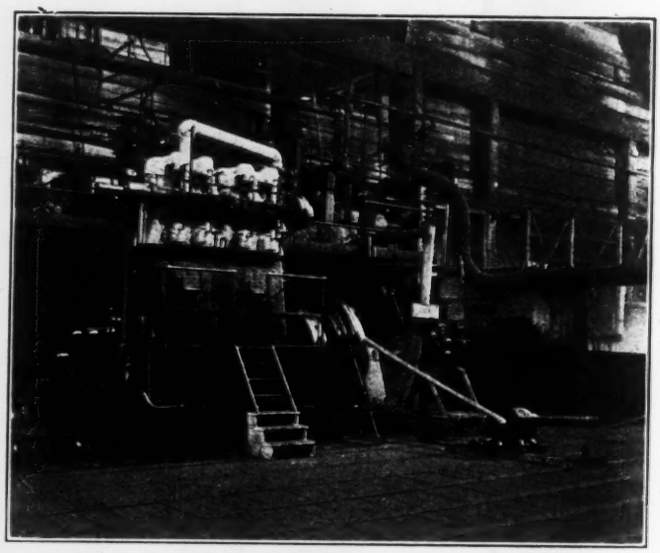


FIG. 1 UNIFLOW ENGINE FOR 400-KW. A.C. GENERATOR EQUIPPED FOR TESTING PURPOSES

TABLE 1 DIMENSIONS OF UNIFLOW ENGINE TESTED

1	Number of cylinders	4
2	Diameter of each cylinder	14 in.
3	Diameter of each piston rod	2⅜ in.
4	Stroke of each piston	16 in.
5	Normal speed	300 r.p.m.
6	Piston speed in feet per minute at 300 r.p.m.	800 ft.
7	Clearance volume in per cent of piston displacement as calculated from drawing, first and second series	22 per cent
8	Clearance volume calculated for third and fourth series	17 per cent
9	Inside diameter of steam pipe	4.8 in.
10	Inside diameter of each of the two exhaust pipes	8 in.

There were four series of tests, each with the four loads specified, namely:

1 Saturated steam, 125 lb. pressure, atmospheric exhaust
2 Saturated steam, 125 lb. pressure, 5 lb. back pressure
3 Saturated steam, 150 lb. pressure, atmospheric exhaust
4 Superheated steam, 150 lb. pressure, atmospheric exhaust.

The leading data and results are presented in Tables 2, 3, 4, and 5.

The steam on all the saturated-steam tests was practically dry steam, a throttling calorimeter, showing almost constantly a temperature of 277 deg. fahr. with 125 lb. pressure at the throttle valve, indicating a moisture content of less than one-half of one per cent. No correction was made for this small amount of moisture.

The superheating boiler of the plant was not in service while the saturated-steam tests were being conducted.

[1] Cons. Steam Engr. Mem. A.S.M.E.

For presentation at the Spring Meeting, Milwaukee, Wis., May 18 to 21, 1925, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. All papers are subject to revision.

Be sure to bring this copy with you to the Spring Meeting

The indicated horsepower was determined by taking diagrams and kilowatt readings simultaneously, and correcting for any departure from the even 100-, 200-, 300-, and 400-kw. loads, which were the points at which the averages were continuously maintained. The diagrams were taken from three-way cocks according to the usual test-block method. The horsepowers should be slightly reduced owing to the error of the three-way cocks. This error, however, is practically offset by a corresponding error due to the reducing motion in use which acts the opposite way, and these errors may be disregarded.

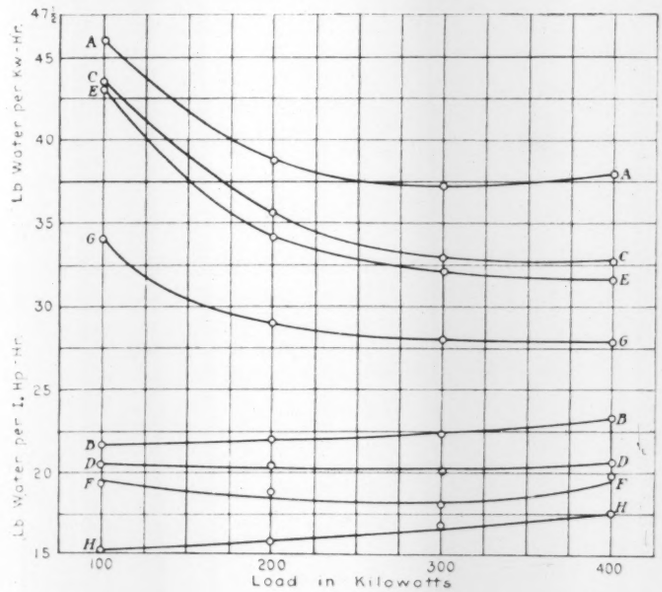


FIG. 2 CURVES SHOWING PERFORMANCES OF THE UNIFLOW ENGINE
Curves A and B: Saturated steam, 125 lb. pressure, 5 lb. back pressure.
Curves C and D: Saturated steam, 125 lb. pressure, atmospheric exhaust.
Curves E and F: Saturated steam, 150 lb. pressure, atmospheric exhaust.
Curves G and H: Superheated steam, 150 lb. pressure, atmospheric exhaust.

TABLE 2 TESTS OF UNIFLOW ENGINE—FIRST SERIES
(Saturated steam, 125 lb. pressure, atmospheric exhaust, 22 per cent clearance)

		Proportionate Load			
		1/4 load	1/2 load	3/4 load	Full load
1	Gage at throttle valve, lb.	125	125	126	125.5
2	Electric load (exclusive of exciter), kw.	100	200	300	400
3	Water per hour, lb.	4360	7144	9908	13,124
4	Indicated horsepower	211.6	350.8	491.8	635.2
5	Water per i.hp-hr., lb.	20.6	20.4	20.1	20.7
6	Water per kw-hr. (exclusive of exciter), lb.	43.6	35.7	33.0	32.8

TABLE 3 TESTS OF UNIFLOW ENGINE—SECOND SERIES
(Saturated steam, 125 lb. pressure, 5 lb. back pressure, 22 per cent clearance)

		Proportionate Load			
		1/4 load	1/2 load	3/4 load	Full load
1	Gage at throttle valve, lb.	125.3	129	124	124.4
2	Electric load (exclusive of exciter), kw.	100	200	300	400
3	Water per hour, lb.	4655	7776	11,203	15,214
4	Indicated horsepower	215.5	352.7	499.4	652.6
5	Water per i.hp-hr., lb.	21.6	22.0	22.4	23.3
6	Water per kw-hr. (exclusive of exciter), lb.	46.1	38.9	37.3	38

TABLE 4 TESTS OF UNIFLOW ENGINE—THIRD SERIES
(Saturated steam, 150 lb. pressure, atmospheric exhaust, 17 per cent clearance)

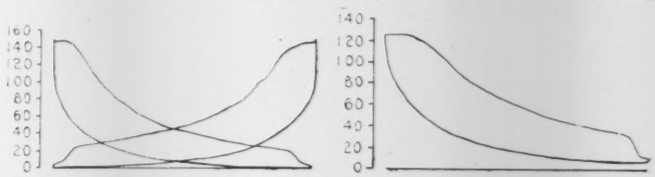
		Proportionate Load			
		1/4 load	1/2 load	3/4 load	Full load
1	Gage at throttle valve, lb.	151	153.2	152.4	150.8
2	Electric load (exclusive of exciter), kw.	100	200	300	400
3	Water per hour, lb.	4314	6834	9668	12,652
4	Indicated horsepower	222.4	361.9	533	634.5
5	Water per i hp-hr., lb.	19.4	18.9	18.1	19.9
6	Water per kw-hr. (exclusive of exciter), lb.	43.1	34.2	32.2	31.6

TABLE 5 TESTS OF UNIFLOW ENGINE—FOURTH SERIES
(Superheated steam, 150 lb. pressure, atmospheric exhaust, 17 per cent clearance)

		Proportionate Load			
		1/4 load	1/2 load	3/4 load	Full load
1	Gage at throttle valve, lb.	153	152	152.2	151.4
2	Temperature by throttle thermometer, deg. fahr.	469	443	427	437
3	Superheating at throttle thermometer, deg. fahr.	109	83	67	77
4	Electric load (exclusive of exciter), kw.	100	200	300	400
5	Water per hour, lb.	3411	5807	8430	11,148
6	Indicated horsepower	223.2	365.2	501.5	633.3
7	Water per i. hp-hr., lb.	15.3	15.9	16.8	17.6
8	Water per kw-hr. (exclusive of exciter), lb.	34.1	29.0	28.1	27.9

The economy results of the various tests are shown graphically by points on Fig. 2, in which horizontal distances represent the load in kilowatts and vertical distances pounds of steam consumed per i.hp-hr. and per kw-hr. In each case a curve is drawn showing what may be considered the average curve of performance. It is interesting to note the effect which superheating produced on the curve H of that series as compared with the corresponding curve F given with saturated steam. In the superheated-steam case the curve is substantially a straight line.

The manner in which the steam is distributed in the cylinders by the use of the uniflow principle and its attending valve mechanism and arrangement of cylinders may be seen by reference to the two sample indicator diagrams reproduced in Figs. 3 and 4. Fig. 3 shows the performance with atmospheric exhaust, and Fig. 4 with a back pressure of 6 1/2 lb.



FIGS. 3 AND 4 SAMPLE INDICATOR DIAGRAMS FROM UNIFLOW ENGINE
Fig. 3: Throttle gage, 153 lb.; back pressure, 0 lb.; m.e.p., 45.1 lb.
Fig. 4: Throttle gage, 125 lb.; back pressure, 6.7 lb.; m.e.p., 42.9 lb.

In connection with the operation of the uniflow principle in this engine, the question of cylinder condensation comes to the front. Table 6 is added with a view of showing the steam accounted for by the indicator diagrams in one of the series of tests with saturated steam, as well as the proportion this bears to the actual steam consumption. The high percentages in the last line of the last two columns (87 and 88 per cent) reveal excellent conditions regarding condensation and leakage.

TABLE 6 STEAM ACCOUNTED FOR BY DIAGRAM IN FIRST SERIES OF TESTS

		Load in Kilowatts			
		100	200	300	400
1	Apparent cut-off, per cent	4.1	8.0	11.2	16.9
2	Steam accounted for by diagrams per i.hp-hr., lb.	13.72	16.96	17.49	18.2
3	Actual steam consumed per i.hp-hr., lb.	20.6	20.4	20.1	20.7
4	Percentage accounted for	66.6	83.1	87.0	88.0

At the close of the second series of tests the admission valves were tested for leakage under a standing pressure, with engine blocked, the steam which leaked being revealed by escape into the air through the indicator piping. There was practically no leakage. When the throttle valve was shut and the steam was retained in the steam chests, the pressure within dropped at the extremely low rate of 5 lb. per min., requiring ten minutes' time to be reduced from 120 lb. to 70 lb

Synopses of Other Spring Meeting Papers

The Parallel Operation of Hydro and Steam Plants

SOME OPERATING AND ECONOMIC FEATURES THAT SHOULD RECEIVE CAREFUL ATTENTION

BY F. A. ALLNER

Gen. Supt., Pennsylvania Water and Power Company, Baltimore, Md., Mem. A.S.M.E.

DUE to the low generating costs of modern steam plants the margin of saving offered by a hydro development is frequently quite small. The utmost utilization of combined hydro-steam-source power, however, has become of greater economic importance in recent years. The economic service of hydro power is usually expressed as replacement value of the equivalent amount of steam power. This comprises two different elements: one, the steam investment cost for the hydro demand service; the other, the steam generating cost for the hydro energy delivered to the load system.

A hydro-steam development that is not equipped with seasonal storage can render the greatest demand service to a given system load if, on the days of greatest steam demand on the system coinciding with minimum flow, the hydro plant supplies the peaks and the steam plant the base of the system load. The greatest energy contribution from the hydro plant is obtained by letting it carry the base portion of the system load during high flow and having the peak portion produced by steam.

General and specific methods are explained by which these economic principles are put into practice. Particulars are given of a system of load signaling by means of small changes in frequency above or below normal which has been found very useful for a more perfect distribution of load during certain hours when it is otherwise difficult to secure the desired division of generation.

Hydro-steam parallel operation may produce a favorable operating combination as these two sources of power can supplement each other to mutual advantage in a number of desirable service features. Inherent limitations which serve to prevent too short a governor traversing time on hydro units are explained, as well as oscillograms of "load on" and "load off" tests recording speed, gate travel, and pressure in wheel pit.

Particulars are given of a proposed ideal hydro-steam parallel operation where the steam station will be located immediately adjacent to the hydro plant. The generating units of both plants will be operated from the same control board. Circulating water for the condensers will be drawn from and returned to the forebay of the hydro plant. During frazil-ice attacks this arrangement is expected to minimize capacity reductions at the hydro plant. There is a natural seasonal diversity in the time of overhauling work at the two types of plants. It will be possible to keep the same skilled labor force employed more steadily throughout the year and to use the same shop facilities for the repair work of both plants.

THE papers, abstracted on this and the following pages are being printed in full in pamphlet form for the Spring Meeting. Copies of them may be secured by filling out the blank on page 447 of this section of the May issue of MECHANICAL ENGINEERING and mailing it to the office of the Society.

The remainder of the papers preprinted for the meeting will be found in this special Section Two of MECHANICAL ENGINEERING.

The tentative program for the Spring Meeting appears on pages 391 and 392 of this section.

Steel-Foundry Management

BY R. A. BULL

Dir., Electric Steel Founders' Research Group, Chicago, Ill.

THE author discusses those steel-foundry problems that in his opinion have the greatest general significance in this highly specialized branch of manufacture. He presents a brief analysis of the industry, explaining its technical and commercial divisions and the significance of each from the standpoint of output, for the purpose of more clearly indicating the nature of the industry under consideration.

Many occupations in the steel foundry are listed in order to explain the complex nature of the operations for which a manager is responsible. The branches of a company organization are assigned to staff and line departments. Reasons are given for certain classifications, regarding which procedures occasionally vary. Policies governing staff departments are discussed separately, not for the purpose of enumerating all duties ordinarily performed, but with the intention of provoking discussion regarding certain factors considered by the author to be of fundamental importance, about which there are differences of opinion.

The subject of compensation both for workmen and for foremen is emphasized because the author believes this is a detail of management which is of very great significance.

Duty Tests of Vertical Triple-Expansion Pumping Engines, Milwaukee, Wis.

RESULTS OBTAINED AT RIVERSIDE PUMPING STATION

BY CHARLES A. CAHILL

Consulting Engineer, Cahill & Douglas, Milwaukee, Wis. Mem. A.S.M.E.

MILWAUKEE, Wisconsin, has equipped its new Riverside Pumping Station with three vertical triple-expansion pumping engines. The reason for this choice of engines of this type was their great reliability, high economy, and low cost of maintenance. The author believes that the units A and B recently tested have shown a duty record that has not been equaled to date by any using steam as a working medium for pumping water.

The Rational Design of Covering for Pipes Carrying Steam up to 800 Deg. Fahr.

BY W. A. CARTER AND E. T. COPE

Respectively, Engineer, Research Dept., The Detroit Edison Co., Mem. A.S.M.E., and Research Dept., The Detroit Edison Co., Detroit, Mich.

THE authors present an analysis of the problem of determining the most economical thickness of pipe covering for steam pipes carrying steam superheated to temperatures of 500 deg. fahr. and above, based on the work of Heilman, Eberle, and others. Two cases are considered, one in which a single insulating material is used, while in the second it is considered necessary to use a material of higher heat-resisting properties between the pipe and the covering used in the first case. Curves showing the net monetary saving for various thicknesses of covering for a 6-in. pipe are included. Equations for the calculations involved are included and the procedure of making the calculations explained. Three appendices deal with some of the assumptions made in the analysis.

Boiler Furnaces for Pulverized Coal

BY A. G. CHRISTIE

Professor of Mechanical Engineering, Johns Hopkins University, Baltimore, Md. Mem. A.S.M.E.

POWDERED coal is used more widely every year for furnaces under boilers. An analysis of the fundamentals of the combustion of the coal and of the effect of radiant heat and flame on the performance of such furnaces is presented in this paper. Certain features secondary to the furnace and dealing with preparing and drying coal and handling ash are also discussed briefly.

This analysis indicates that the following conditions are de-

sirable for the highest efficiency and maximum capacity of a given furnace: Coal should be finely ground, thoroughly dry, and preheated before entering the furnace. Primary and secondary air should be highly preheated. Turbulence should exist inside the furnace. The walls should be water-cooled. New methods of handling ash and preventing the discharge of dust into the air should be developed. These will lead toward greater capacity for a given furnace volume and to high boiler efficiencies.

Lake Waters for Condensers

By A. G. CHRISTIE

Professor of Mechanical Engineering, Johns Hopkins University, Baltimore, Md. Mem. A.S.M.E.

THIS paper points out the persistence of stratification of warm- and cold-water layers in our northern lakes and other deep waters. The cold bottom layers make excellent cooling-water supplies for condensers and would permit operation at high vacuum throughout the whole year. The savings from increased vacuum are such that engineers should give this factor careful consideration, both in the selection of plant site and in the design of intakes, particularly for large power stations. Temperature-depth studies of the particular lake should be made to furnish exact data upon which a rational decision can be based.

A Review of Steam-Turbine Development

By HANS DAHLSTRAND

M.E., Steam Turbine Engrg. Dept., Allis-Chalmers Mfg. Co., Milwaukee, Wis. Mem. A.S.M.E.

THIS paper is chiefly concerned with the effects which the use of steam at higher pressures and temperatures has had upon the efficiencies of steam turbines and upon the materials used in the construction of their parts. The use of high-back-pressure steam turbines, to be installed in connection with boilers of higher pressure in such a way as to exhaust into the steam mains and turbines of existing plants, is carefully analyzed for units of 10,000- and 30,000-kw. capacity, and the effects on the efficiency are graphically presented. A discussion of materials for use with the higher pressures and temperatures is included, with some curves showing the results of investigations made by the Allis-Chalmers Company on various metals and the characteristics which should be possessed by a metal suitable for use at 1000 deg. fahr. The paper also contains some comments on corrosion and erosion of turbine blades, and shows the effects of these destructive forces on blades of different composition.

Mechanical Features Affecting the Reliable and Economical Operation of Hydroelectric Plants

Translated by L. C. Marburg, Mem. A.S.M.E.

By E. A. DOW

Mechanical Engineer, New England Power Construction Co., Worcester, Mass.

THIS paper deals with the subjects of flashboards, trashracks, rack rakes, sluice and headgates, penstock valves, air vents, and discharge-measuring devices from the standpoint of economy and reliability of operation based almost entirely on the New England Power Company's practice. It stresses the importance of reducing head losses and leakage and adhering to strength and simplicity in the design of hydraulic equipment.

Comparison of Actual Performance and Theoretical Possibilities of the Lakeside Station

By M. K. DREWRY

Technical Engineer, Power Plants, Milwaukee Electric Railway & Light Co., Milwaukee, Wis. Jun. A.S.M.E.

TO SHOW the degree of perfection in the design and operation of a high-efficiency, straight Rankine-cycle station, pointing out the magnitude of each individual heat and availability loss occurring in actual practice, is the object of this paper. Operating and test figures of the Lakeside Station have been assembled and a comparison of theory and practice has been recorded.

Recent Investigations in Turning and Planing and a New Form of Cutting Tool

By HANS KLOPSTOCK

Pres., Klopstock Steel Co., Berlin, Germany

THIS paper gives an account of experiments conducted in the machine-tool laboratory of the Polytechnic Institute of Berlin. The cutting tests proper were preceded by a study of the lathe and the instruments used, to ascertain their behavior under various conditions. In the main tests it was aimed to determine the influence upon the cutting forces of the following factors: Cutting speed, chip section, shape of tool, and characteristics of the materials cut.

As a result of these observations a new form of tool has been designed which, the author claims, permits a higher cutting speed and a larger chip section than is practicable with the standard tools now used. The results of some of the tests made in various German railway shops are given, in which the relative life of the cutting edges of the new and the old tools under exactly the same conditions was compared.

It is claimed, from results obtained in various foreign shops, that on the average production can be increased about 30 per cent by means of the new tool.

Torsional Vibrations and Critical Speeds of Shafts

By ARNOLD LACK AND CHARLES B. JAHNKE

Respectively, Engineer and Chief Engineer, Fairbanks, Morse & Co., Beloit, Wis.

THIS paper is an analysis of torsional vibrations and critical speeds of shafts. These magnitudes, as shown in the paper, can be calculated for any engine when all necessary data are given. The various characteristics of torsional vibrations are measured with a special instrument called the "Torsiograph," which shows by means of "torsiograms" the degree of irregularity of rotation of the shaft.

The stresses in the shaft due to its vibrations are also computed, and means of avoiding dangerous vibrations are shown. Results of a number of tests are given, which were carried out on: (*a*) an apparatus for demonstration of torsional vibrations; (*b*) an experimental horizontal oil engine; (*c*) a vertical two-cylinder Diesel engine driving two generators; (*d*) and a vertical four-cylinder marine engine.

Stress Concentration Produced By Holes and Fillets

By S. TIMOSHENKO AND W. DIETZ

Research Laboratory, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa. Respectively, Mem. A.S.M.E. and Non-Member.

IN MANY practical cases a very high stress concentration is produced by holes, grooves, notches, and sharp variation of cross-sections. This stress concentration is particularly undesirable where materials undergo reversal of stress. Coefficients of safety as hitherto employed have been large enough to cover such weakness. The modern tendency in design is to increase working stresses, thereby obtaining lighter and more economical structures, and concentration of stress is accordingly receiving more attention than formerly.

The authors attack a number of practical problems relating to holes and fillets, and employ several methods of approach: namely, analytical method giving approximate solutions for certain simple cases; photoelastic method, by means of which stress concentration can be studied if the problem is a two-dimensional one; Lueders' line method, or the study of certain lines appearing on the polished surfaces of a mild-steel specimen subjected to simple tension or compression, at the points of highest stress concentration; and fine extensometer measurements at points of stress concentration. Analytical and experimental methods are found by the authors to be in satisfactory agreement as far as static loads are concerned. When reversal of stress is involved, the weakening effect of stress concentration can only be established accurately on the basis of fatigue tests.

The Activated-Sludge Sewage-Disposal Plant at Milwaukee

Its General Operation and the Fundamental Principles Involved

By JOHN ARTHUR WILSON

Consulting Chemist, Sewerage Commission of Milwaukee.

THE problem confronting the Milwaukee Sewage Commission at the beginning of its work in 1913 was to separate the city's sewage—now having a flow of 85,000,000 gal. daily—into an effluent pure enough to discharge safely into Lake Michigan, its source of drinking water, and dry solid matter in a form permitting its economical shipment and use as a fertilizer. The activated-sludge process was adopted, which took care of the effluent part of the problem, and after prolonged and intensive engineering and chemical research a method was devised for reducing the sludge to an attractive dry powder with a high fertilizer value. The paper discusses in detail the methods used in removing both coarse and finely divided materials from the sewage, the mechanism of aeration, various phases of the sludge problem, relative filtering efficiency, effect of adding acid and aluminum sulphate, dewatering the sludge, preparation of the dry material as fertilizer, etc.

Radiation in the Pulverized-Fuel Furnace

By WALTER J. WOHLENBERG and DONALD G. MORROW

Respectively Associate-Professor of Mechanical Engineering, Yale University. Assoc-Mem. A.S.M.E., and Student at Yale University, New Haven, Conn.

THIS paper deals with the fundamentals concerning radiation in the pulverized-fuel furnace. It is shown that the radiating power through the flame surface depends primarily on the size of the particle and that, based on the flame-surface area, its magnitude relative to black radiation is low. The heat-absorption intensity at the cold surface, however, may be considerably higher than the relative radiance of the flame. This factor depends on both the amount and the disposition of the refractory furnace lining. Application of the method outlined enables, by an analytical process, quantitative evaluation of the furnace energy process, and the data yielded are of such a nature as to indicate by comparison which furnace proportions will give the best results.

A Code of Design for Mechanical Springs

By JOSEPH K. WOOD

Consulting Engineer, New York, N. Y. Mem. A.S.M.E.

THIS paper first gives an entirely new derivation of the general spring formulas developed by the author from the numerously scattered orthodox spring formulas and presented in his paper on Mechanical Springs at the A.S.M.E. Annual Meeting in December, 1924. The two sets of formulas, although derived independently, are identical in fabrication of terms, and since the new derivation is based upon the direct application of the individual terms, this agreement establishes the general formulas on a more logical and practical basis. There are slight differences, however, in the specific values of the stress-method and form-of-section constants, which in the case of springs of the uniform-flexure type account exactly for differences which have been found between calculated and actual test results. Complete research is urged to confirm this finding definitely, and until such work is done the author will employ the constants that agree with the orthodox formulas. In view of the remarkable manner in which the new derivation establishes the logical arrangement of the generalized formulas, the author has drawn up and included in the paper a brief code of design for mechanical springs, which he is led to believe will serve as a nucleus for a more complete and final code in the future.

Contributors to this Issue

L. V. ANDREWS

L. V. Andrews, author of the paper on A Microscopic Study of Pulverized Coal, was born in Stewardson, Ill. He attended high school in Decatur, Ill, and later studied courses given by the International Correspondence Schools and the Alexander Hamilton Institute. He has been connected with the Lyon Lumber Co., the Mississippi Valley Structural Steel Co., the McLaughlin Coal Reduction Co., all of Decatur, Ill., and the Riley Stoker Corporation, Worcester, Mass. He is at present employed with the latter company in its development department, where he has been working since 1918 with pulverized-coal equipment. During 1918 he was stationed at Carnegie Institute of Technology, Pittsburgh, with the 298th Aero Squadron.

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G. H. BARRUS

G. H. Barrus, consulting engineer, of Boston, Mass., writes on Tests of a Uniflow Engine. Mr. Barrus was graduated from the Massachusetts Institute of Technology in 1874 with the degree of B.S. in mechanical engineering, and then served for six years as engineer for George B. Dixwell, who provided and donated to M.I.T. the first steam laboratory used in any technical school or college in the United States, and which was employed for the Dixwell investigations on superheated steam. From 1880 to the present time Mr. Barrus has been engaged in the consulting field in steam engineering, and has numbered among his clients many manufacturing establishments. In the course of his work he has conducted over a thousand boiler tests and has taken over 25,000 indicator diagrams.

Mr. Barrus has been very active in the work of The American Society of Mechanical Engineers, serving as a member of a number of important committees. He is the inventor of the Barrus steam calorimeter, a draft gage and a steam meter, as well as of drainage improvements for paper-machine driers. He was a Massachusetts member of the Board of Judges of the World's Columbian Exposition in 1893, and was a member of the National Advisory Board on Tests of Fuels and Structural Materials appointed by President Roosevelt.

W. L. DEBAUFRE

William L. De Baufre, who presents in this issue an Analysis of Power-Plant Performance Based on the Second Law of Thermodynamics, is chairman of the mechanical-engineering department of the University of Nebraska. He is also consulting engineer for the U. S. Bureau of Mines, being a member of the Board of Helium Engineers and of the Advisory Committee on the Use of Oxygen or Oxygenated Air in Metallurgical and Allied Processes. For a number of years he was mechanical engineer at the U. S. Naval Engineering Experiment Station, Annapolis, Md.

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H. S. FALK

Harold S. Falk, vice-president and works manager of the Falk Corporation, writes on A National Apprenticeship Program. Mr. Falk was born in Milwaukee, Wis., where he attended both grammar and high school. He then entered the University of Wisconsin, from which he was graduated in 1906. His summer vacations during the school period were spent working in various departments of the Falk Corporation, manufacturers of heavy-duty oil engines, gears, and steel castings. Upon being graduated he entered the employ of that concern as assistant to the superintendent. Sometime later he was appointed superintendent, then general superintendent of the plant, and in 1923, vice-president and works manager.

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P. V. FARAGHER

P. V. Faragher, co-author with R. L. Streeter of the paper on Aluminum and Its Light Alloys, received his A.B. from the University of Kansas in 1909 and then spent four years in graduate study at the University of Kansas, the University of California, and the research laboratory of physical chemistry of the Massachusetts Institute of Technology, receiving his Ph.D. from the latter in 1913. He then returned to the University of Kansas where he held the position of assistant professor, later becoming associate professor of chemistry. During 1918 he held a fellowship at the Mellon Institute of Industrial Research, where he studied the properties of magnesium and its alloys. In 1919 he entered the employ of the Aluminum Co. of America, where he first worked in the research bureau, later becoming connected with the company's technical direction bureau.

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G. E. HAGEMANN

G. E. Hagemann, co-author with J. A. Shepard of Formulas for Computing the Economies of Labor-Saving Equipment, was graduated from Rutgers University in 1912 with the degree of B.S. in mechanical engineering. He worked for a year with Frank B. Gilbreth in his management - installation work at the New England Butt Co., Providence, R. I., and then for a brief period was connected with the Worthington Pump & Machinery Corporation in centrifugal-pump and water-meter testing. For five years he served as an instructor in mechanical engineering at the University of Pennsylvania, and then became mechanical engineer for the Warren Foundry & Pipe Co. in Phillipsburg, N. J. Four and a half years later he accepted his present position of associate editor of *Management and Administration.*

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J. FLETCHER HARPER

J. Fletcher Harper, author of Defects in Large Forgings, attended the University of Wisconsin for three and one-half years, taking the course in electrical engineering, following which he served a special apprenticeship course at the Allis-Chalmers Manufacturing Co. He was connected with an electrical company in Milwaukee for one year, returning to the Allis-Chalmers Manufacturing Co. in July, 1916, to take charge of the heat-treating departments. In September, 1918 he was made assistant superintendent of the forge department in the same plant, and in April, 1921, was appointed research engineer of the manufacturing department of the company, which position he now holds.

GEORGE LANGFORD, JR.

George Langford, Jr., author of the paper on An Application of the Formulas for Computing Economies of Labor-Saving Equipment, was graduated from the engineering college of the University of Minnesota in 1924 with the degree of B.S. in mechanical engineering. Since then he has been connected with the Belden Manufacturing Co., of Chicago, Ill., in the capacity of assistant engineer.

* * * * *

E. H. LICHTENBERG

Erich H. Lichtenberg, author of Labor-Saving Equipment in Road Construction, is chief engineer of the Koehring Co., Milwaukee, Wis. He was educated in the University of Wisconsin extension school, the International Correspondence School, and the Alexander Hamilton Institute. He was for one year in the employ of the Louden Machine Co., Fairfield, Iowa, and from 1906 to 1907 served as patent-office draftsman in Springfield and Chicago, Ill. Later he designed and had charge of the building of ore-reduction machinery for the Kent Ore Reduction Co., of Chicago and Milwaukee, and of the designing of special machinery for the Whitman & Barnes Co., West Pullman, Ill. He has been associated with the Koehring Co. since 1911.

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I. E. MOULTROP

I. E. Moultrop started his engineering career in 1882 by going with the Whittier Machinery Co. of Roxbury, Mass., as an apprentice in the machine shop. Following his apprentice term he went into the drafting room, and in due course was promoted to be head draftsman. He stayed with them until 1892 when he resigned to accept a position as engineer on mechanical construction work with the Boston Edison Company, and has been with that company ever since, advancing progressively to the position which he now holds, assistant superintendent of the construction bureau, which Bureau handles all the construction work done by the company.

Mr. Moultrop is at present a member of the A.S.M.E., A.I.E.E., Boston Society of Civil Engineers, N.E.L.A., and Association of Edison Electric Illuminating Companies. He is also a member of the Boiler Code Committee and Power Test Code Sub-Committee on Turbine Testing of the A.S.M.E.

Mr. Moultrop's prominence in the activities of the engineering work of the N.E.L.A. has been an outstanding feature of his career. He has served on its Prime Movers Committee, and the Steam Turbine and Gas Engineering Committee which proceeded the Prime Movers Committee, some ten or twelve years.

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EDWARD W. NORRIS

Edward W. Norris is a mechanical engineer, with Stone & Webster, Inc. He was graduated from the University of Pennsylvania in 1911 and joined the Society the following year. For five years he was in the engineering department of the Southwark Foundry and Machine Co., designing power-plant equipment and doing research work. He then spent a year with the Mead-Morrison Manufacturing Co. During the War he went to the Hog Island Shipyard where he supervised the installation of machinery and was later master mechanic at the structural fabricating shops. He went to Boston in 1919 with the C. B. Roberts Engineering Co., petroleum engineers, having charge of fuel oil installations. Three years later he entered the Engineering Division of Stone & Webster, Inc., taking the position he now holds.

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J. A. SHEPARD

J. A. Shepard, co-author with G. E. Hagemann of Formulas for Computing the Economies of Labor-Saving Equipment, is vice-president and consulting engineer of the Shepard Electric Crane & Hoist Co. From 1880 to 1893 Mr. Shepard was one of three partners in the firm of W. H. Shepard & Sons, manufacturers of agricultural implements in Montour Falls, N. Y., where he served successively as molder, patternmaker, machinist, draftsman, salesman, and business manager. For the next nine years he was chief engineer of the W. H. Shepard & Sons' Bridge Co., in charge of the design and construction of plant and products. From 1902 to 1908 Mr. Shepard was chief engineer of the General Pneumatic Tool Co., the successor to the company with which he had just previously been connected. This concern in turn became the Shepard Electric Crane & Hoist Co., which Mr. Shepard served as vice-president and chief engineer before being appointed to his present position.

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Lewis K. Sillcox, general superintendent of motive power of the Chicago, Milwaukee & St. Paul Railway Co., writes on Factors Concerning the Economics of Shopping Steam Locomotives. Mr. Sillcox is a graduate of the Institute of Mechanical Engineers, Brussels, Belgium, receiving his M.E. in 1903. For three years immediately after he was connected with the New York Central Lines where he learned the machinist's trade and operating methods in the mechanical department. He was then for one year connected with the McSherry Manufacturing Co., Middletown, Ohio, as assistant general shop superintendent, resigning to become mechanical engineer in charge of the design of equipment and shops of the Illinois Traction System, Decatur, Ill. From 1910 to 1912 Mr. Sillcox was with the Canadian Car & Foundry Co., in Montreal, Canada, and for the next four years was associated with the Canadian Northern Railway System, Toronto, as mechanical engineer in charge of the design of locomotives, cars, shop tools, etc. In 1916 he accepted the position of mechanical engineer in charge of car work for the Illinois Central Railroad, Chicago, Ill., and shortly afterward became master car builder for the Chicago, Milwaukee & St. Paul Railway Co., of which concern he is now general superintendent of motive power.

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R. L. STREETER

R. L. Streeter and **P. V. Faragher** are co-authors of the paper on Aluminum and Its Light Alloys. Mr. Streeter is a 1903 graduate of the University of Pennsylvania. He engaged in practical engineering work until 1910, when he became connected with Rensselaer Polytechnic Institute as assistant professor of mechanical engineering. He served in the Army from May to October of 1919, and upon receiving his discharge became chief mechanical engineer of the Aluminum Co. of America. He is now vice-president of the United States Aluminum Co. in charge of the fabricating plants.

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R. J. Wadd, who writes on Economic Efficiency of the Full-Automatic Turret Lathe in Comparison with the Semi-Turret Lathe, has been since 1921 chief engineer of the Shepard Electric Crane & Hoist Co., Montour Falls, N. Y. He received his B.S. in mechanical engineering from Michigan Agricultural College and then entered the employ of the Shepard Electric Crane & Hoist Co., on engineering and sales work. During the war he was connected with the Chemical Warfare Service, returning to the Shepard Co. upon being discharged from the Army.

The following papers, to be presented at the Milwaukee Spring Meeting, will be available in pamphlet form and may be secured without cost by any member of the Society.

Check papers desired and mail to the Secretary.

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Spring Meeting Papers Available

Distribution of these papers by mail will commence about May 1

Check Here (X)	Authors and Papers	Date Shipped	By
	ALLNER, F. A., The Parallel Operation of Hydro and Steam Plants		
	BULL, R. A., Steel-Foundry Management		
	CAHILL, CHARLES A., Duty Tests of Vertical Triple-Expansion Pumping Engines, Milwaukee, Wis.		
	CARTER, W. A., and COPE, E. T., Rational Design of Covering for Pipes Carrying Steam up to 800 Deg. Fahr.		
	CHRISTIE, A. G., Boiler Furnaces for Pulverized Coal		
	CHRISTIE, A. G., Lake Waters for Condensers		
	DAHLSTRAND, HANS, A Review of Steam-Turbine Development		
	DOW, E. A., Mechanical Features Affecting the Reliable and Economical Operation of Hydro-electric Plants		
	DREWRY, M. K., Comparison of Actual Performance and Theoretical Possibilities of the Lakeside Station		
	KLOPSTOCK, H., Recent Investigations in Turning and Planing, and a New Form of Cutting Tool		
	LACK, A., Torsional Vibrations and Critical Speeds of Shafts		
	TIMOSHENKO, S., and DIETZ, W., Stress Concentration Produced by Holes and Fillets		
	WILSON, JOHN A., The Activated-Sludge Sewage-Disposal Plant at Milwaukee		
	WOHLENBERG, WALTER J., and MORROW, DONALD G., Radiation in the Pulverized-Fuel Furnace		
	WOOD, J. K., A Code of Design for Mechanical Springs		

TO THE SECRETARY, A.S.M.E., 29 West 39th Street, New York City.

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SPRING MEETING A.S.M.E. MAY 18-21, 1925

MILWAUKEE

and while here, take advantage of the opportunity to meet in person the executives of concerns in whose products you are interested. In many cases you will be able to see new machines in operation, or to secure first-hand information about manufacturing processes which will be of direct benefit from a business or professional standpoint. On the following color pages, the concerns located here present special information regarding their products and extend a cordial invitation to visit their plants, (see map on pages 2 and 3).

Manufacturers Represented in this Special Color Section

	Map Loc.	Page No.
Albaugh-Dover Mfg. Co	Chicago	30
Allis-Chalmers Mfg. Co	Milwaukee	10, 11
Bailey Meter Co	Cleveland	28, 29
Carrick Engineering Co	Chicago	15
Chain Belt Co	Milwaukee, O-10	13
Combustion Engineering Corp'n	New York	24
Conveyors Corp'n of Amer	Chicago	17
Detrick, M. H. Co	Chicago	20
Edge Moor Iron Co	Edge Moor	25
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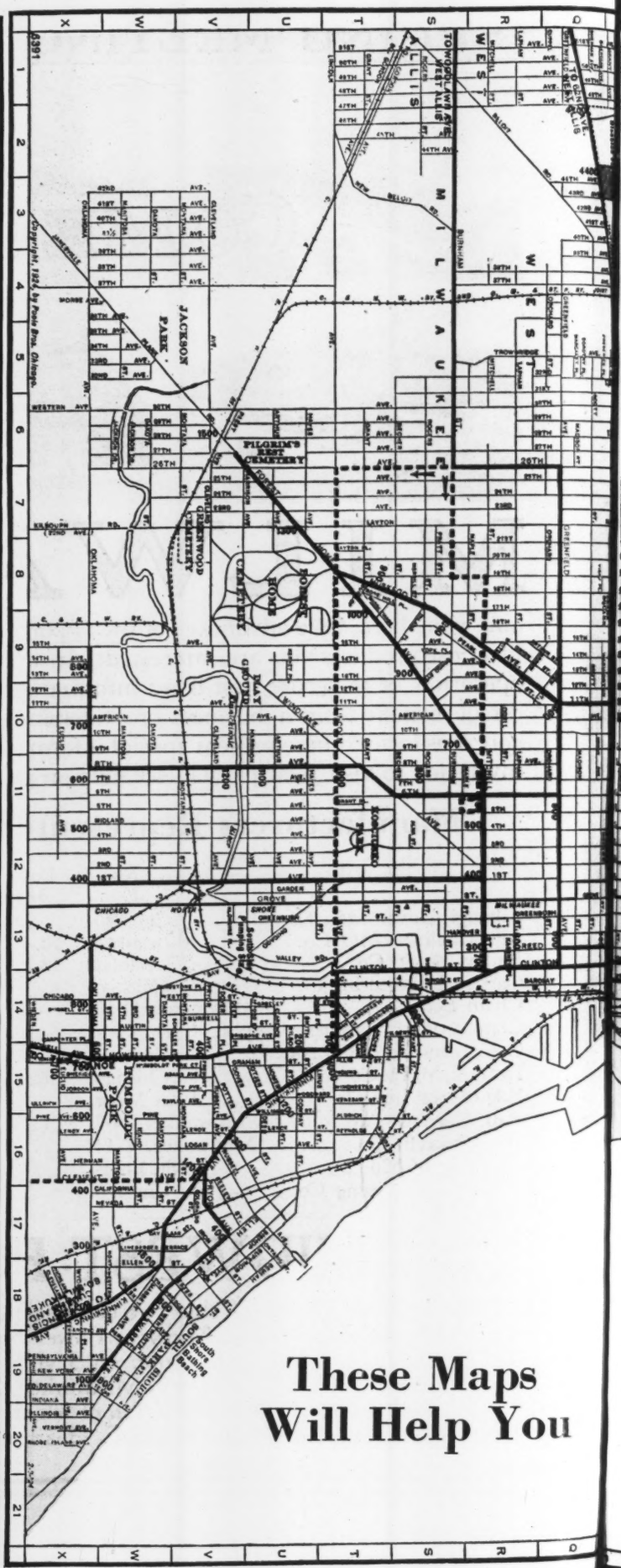
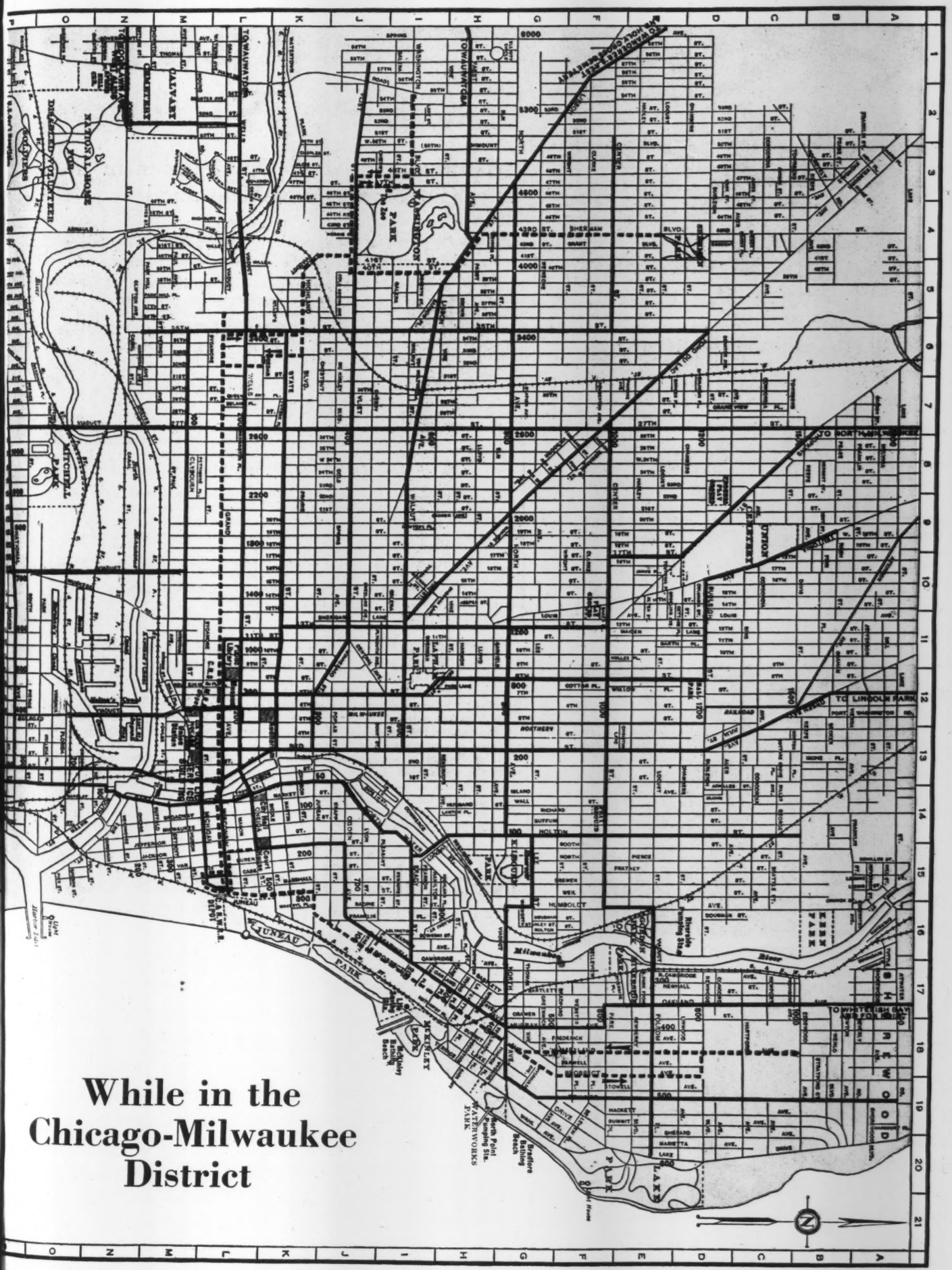
Filer-Stowell Co	Milwaukee, T-14	8
Heine Boiler Co	St. Louis	19
Illinois Engineering Co	Chicago	21
James, D. O. Mfg. Co	Chicago	6
Johnson Service Co	Milwaukee, L-15	12
Kellogg, M. W. Co	New York	23
Midwest Power Show (Inc.)	Milwaukee, K-12	31
Nordberg Mfg. Co	Milwaukee, X-14	9
Permutit Co	New York	27
Republic Flow Meters Co	Chicago	4, 5
Ric-wil Co	Chicago	14
Riley Stoker Corp'n	Worcester	22
Schutte & Koerting Co	Philadelphia	16
Techno Service Corp'n	New York	18
Union Iron Wks	Erie	26
Vilter Mfg. Co	Milwaukee, T-14	12
Wrought Washer Mfg. Co	Milwaukee, T-16	14

MIDWEST POWER SHOW

On page 31 of this two color section is presented an announcement from the Management of the Midwest Power Show and Mechanical Exposition which includes the list of Exhibitors. A.S.M.E. Members are urged to attend this Exposition which will be held in Milwaukee, May 18 to May 22 inclusive, at the Municipal Auditorium; the location of which on the map (pages 2 and 3) is K-12, only a short distance from A.S.M.E. Headquarters at the Hotel Pfister, L-14.



These Maps Will Help You


While in the
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District